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Selection of Apprentices in the Engineering Industry

ENGINEERING firms depend largely on today's apprentices for their future supplies of technicians and craftsmen. Since the training is long and costly, and mistakes in selection cannot easily be rectified, it is important that firms in a position to pick and choose should have a reliable system of assessing the suitability of candidates for apprenticeship.

Encouraging results are reported from a method of selection which has been devised by the National Institute of Industrial Psychology and which so far has been adopted by about fifty firms. A special feature of the procedure is a battery of tests designed to provide objective measures by which the abilities considered important for success in engineering occupations can be assessed.

In selecting candidates for any kind of training, it is logical to study the job, in order to decide what qualities will be required by those who are to perform it. The next step is to assess applicants, to find out how far their qualities meet the requirements of the job. There are three yardsticks which, if efficiently applied, enable reliable assessments to be made. In the first place, personal history is a useful guide to what may be expected of an applicant in the future. Secondly, general intelligence, special aptitudes, and attainments can be examined by simple tests. Finally, the data obtained by the first two methods can be related to the other aspects of the candidate's make-up during a personal interview, on which the ultimate decision will be based.

Mechanical aptitude is an essential requirement in the engineering industry and, as in all skilled occupations, a level of intelligence is also most important. Arithmetical ability is desirable, because calculations are an integral part of engineering work. These are all qualities which can be objectively measured, and a valuable indication of a candidate's interests can also be obtained by means of suitable tests. Included, therefore, in the battery of tests used by the National Institute of Industrial Psychology, are tests for intelligence, for mechanical ability, for mechanical information, for judgment of spatial relations, and for elementary mathematics.

Two types of intelligence test are used :—In the first type, problems are posed verbally, the questions being answered by indicating words which are out of order in a particular group, or by selecting from a number of words the one which fills a particular relationship.

In the other type, the problems are posed by diagrams and diagrammatic relationships. Tests of this nature are usually a more accurate criterion of pure intelligence, because the results are not influenced by education. To obtain an accurate picture of the candidate's intelligence, however, it is considered desirable to use both types.

Since diagrams are an unfamiliar medium, each section of the " non-verbal " intelligence test is introduced by a practice section, thus ensuring that the candidates understand what is required of them before any work is done on the actual test. This also helps to put candidates at ease. The first section tests their ability to perceive simple relationships. The candidate might, for instance, be shown two simple diagrams and asked what must be added to one to make it into the other, or he might be shown three diagrams, A, B, and C, and asked to find a fourth diagram, D, which is to C as B is to A. Another part of the test introduces classification problems, such as the re-arrangement of a number of lines in correct order of length. The test of ability to judge spatial relations involves problems of fitting two-dimensional and three-dimensional shapes. In the earlier sections of this test, the candidate has to choose from a number of alternative pieces of the correct shape to complete a series of squares with missing sections. In the first series of problems, the shapes have to be turned round before they will fit into the squares. Then, the candidate has to deal with still more involved shapes, and also with shapes which have to be turned both round and over. In the sixth section, two pieces of different shapes are required to fill the space in each square. Finally, there are problems of a three-dimensional type, in which candidates have to find the missing pieces to make up complete cubes.

Understanding of simple mechanisms is measured by a test in which a series of eight models is mounted on one side of wooden boards, the actual mechanisms being partly concealed by the board from the candidate, who can see only arms, weights, wheels, and other components, extending beyond the edges of the board and moving up and down or revolving when the mechanism is operated. For each model the candidate is given eight problem diagrams and has to state for each diagram whether or not it represents a mechanism which will produce the same action as the model being demonstrated.

Arithmetical ability is measured by questions designed to test basic knowledge of the subject, these being followed by a few types of workshop calculations, starting with very simple problems.

The practical assembly test is to some extent a measure of mechanical ability, but serves also as a useful indicator of the candidate's interest in practical subjects, i.e., how far he has shown an interest in taking things to pieces to find out how they work. Each candidate is given nine objects in common use, broken down into their component parts, and is required to assemble them. The remaining test is one of knowledge of everyday mechanical practice and of terms with which a candidate should be familiar, if he has taken an interest in practical constructional hobbies.

In all the foregoing tests the answer to each question can only be right or wrong, the candidate's score being entirely unaffected by the mood of the examiner. By the time a group has been put through this battery of tests, the strong points and weaknesses of each candidate have been spotlighted.

In all tests, items are graded in order of difficulty, so that candidates are encouraged by the ease with which they are able to solve the initial problems. If several candidates completed the whole of the test correctly, there would be no means of discriminating between them. The time limit is therefore such that no candidate is expected to find all the answers within

the period allowed. With the exception of the assembly test, all tests are conveniently given to a number of candidates simultaneously.

Different standards are applied to different groups, so that the abilities of the candidates tested can be related to those of boys with similar background and experience. Test scores are first expressed in terms of marks but, for ease of interpretation, are converted into grades on a five-point scale, *viz.*: *A*—well above average; *B*—above average; *C*—average; *D*—below average; and *E*—well below average.

It is considered inadvisable to give points for grades. Since a candidate who obtained an *A* and an *E* in two tests would have the same number of points as one who obtained two *C*s, a more accurate picture is obtained by regarding the pattern of results as a whole.

The tests are being used to determine, not the suitability of candidates for a particular trade, but their general suitability for engineering apprenticeship. They do discriminate, however, between those with the potential ability to become technicians, those of more limited ability who will make good tradesmen, and those who are unsuitable for apprenticeship.

The ideal method of evaluating a battery of tests is by engaging candidates in the normal manner, testing them soon after engagement, and, after they have completed their training, comparing their performances in terms of the rating with their test performances at the time of recruitment. Owing to National Service, however, it might be as long as seven years before such a comparison could be made. Since commercial firms cannot reasonably be expected to use the procedure for an experimental period of up to seven years, a more speedy method of evaluation is required. The effectiveness of the tests has therefore been checked by administering them to existing apprentices at known levels of ability.

The suitability of an individual for a particular job is usually considered under seven headings :—Physical requirements, attainments (educational and other), general intelligence, special aptitudes, interests, disposition, and background circumstances. Since the tests provide information on only two or three of these points, complete correspondence between test results and performance should not be expected. Different districts have different standards, while practice within the industry also varies considerably. Some firms select apprentices for individual jobs; others engage all boys initially as general trade apprentices, while still others divide them into engineering apprentices, craft apprentices, and laboratory apprentices. Few firms have

(*Concluded on page* 450)

Machine Control by Magnetic Record Playback

By H. Wilkin Perry

Automatic control of production machine operations by means of magnetic tape recordings is one of the latest developments in metal working. The most recent application of the method, which has been undergoing development by the General Electric Company, U.S.A., for the last five years, is to a milling machine built by the Giddings & Lewis Machine Tool Company in the United States for use in machining self-reinforced skin for aircraft construction. Engineers of the tool company expect that the control equipment, which is to be delivered this year, will double production speed of the machine.

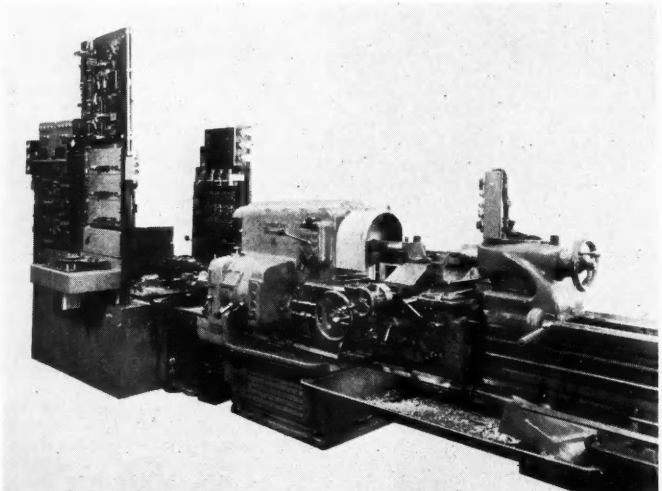

Fig. 1. **Record-playback control system for a 16-in. lathe.**

Factors which contribute to faster production and lower costs when record-playback control is used are as follows :—

(1) No templates are required, so that storage space, handling, and setting-up time are eliminated; thus, machine time can be almost entirely productive.

(2) No stopping of a machine is necessary for gauging or checking the work against blueprints, because each successive part produced is identical with an accurately made prototype.

(3) Operator errors are avoided and wastage of material is reduced, if automatic record control of the machine operating cycle is proved correct by producing a test duplicate of the original.

(4) Many normal operator motions become unnecessary, and a machine can be run continuously after the sequence of operations has been recorded on tape.

(5) Less factory space is required, if smaller machines without tables for templates are built.

(6) Fully automatic production of parts which are too complex or time-consuming for manual operations is possible, and the accuracy of all duplicates is assured.

(7) Parts inventory may be reduced, because the minimising of machine set-up time and production costs permits the making of small quantities of parts, as needed.

It is asserted that control by playback of magnetic tape recordings has almost unlimited industrial applications. It can be used for programming operations of lathes, die-sinking machines, flame cutters, and various other machine tools;

and to programme conveyor speed, the opening and closing of valves, the density and flow of fluids, and weight, pressure, temperature, and humidity.

Engineers of the General Electric Company state, however, that the method is not economically practical at present for many possible applications, because the control equipment must be engineered to suit each individual installation and must be co-ordinated with the design of the machine the tape record is to control; it is, therefore, relatively quite expensive. Machine or process variables, such as tools, procedure, speed, and specified accuracy, must be suited to application of the method. It is very important that machines be designed or modified by the manufacturers to adapt them to successful operation by record-playback control. For instance, to adapt a 16-in. lathe for tape-record control, the longitudinal carriage feed and the cross-slide feed were powered separately, instead of being geared to the headstock and to each other, so that the two motions could be recorded individually. Then, with playback control by a multi-channel tape record, the lathe was able to machine shafts at a feed rate of 15 inches per minute and with an accuracy of $\pm$ 0·001 in. Fig. 1 shows a developmental record-playback programme control system for a 16-in. lathe. The magnetic recorder and other control equipment are at the left of the illustration; the operating controls can be seen above the tailstock.

Commercially available standard recorders are designed for the use of magnetic tape of $\frac{1}{4}$-, $\frac{1}{2}$-, $\frac{3}{4}$-, and 1-inch widths and for recording in as many as fourteen channels per inch width. The tape is made of plastic, coated with a magnetisable powder.

Two methods of making tape records for automatic production of complex parts are at present in use. One method is for an expert operator to machine manually an accurate prototype part while the machine motions and switching operations are recorded. The other method is to mount a tracer head on a machine, so that it will follow the outline or contour of a template, pattern, or sample part, similarly to a cutting tool. An operator then puts the machine through its cycle and the motions and switching operations are recorded on a tape.

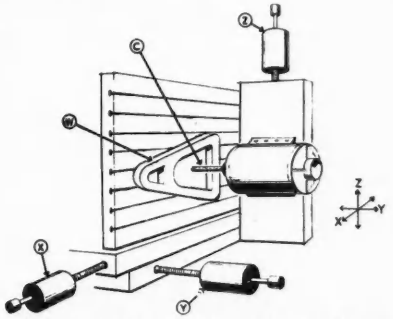

Fig. 2. **Recording of feed motions of a manually operated machine by means of three selsyns.**

Records of feed motions of manually operated machines are made by means of three selsyns (synchros), each coupled to one of three adjustable-speed, direct-current feed motors, as shown in Fig. 2. Two of these motors (X) and (Y) feed horizontally at an angle of 90 deg. to each other, and the third motor (Z) feeds vertically. The selsyns continuously send to the moving tape electric signals of the angular positions of the three motors relative to the workpiece (W) and the cutter (C), and these signals are recorded magnetically. Movement of the tape ceases when the operator stops the machine to check accuracy of the work or to make machine adjustments. Thus, only actual machine operation is recorded, plus any on-off actions, such as starting and stopping tool-drive motors, turning coolant on and off, and other operations usually started and stopped by pushing a button or by automatic time switches.

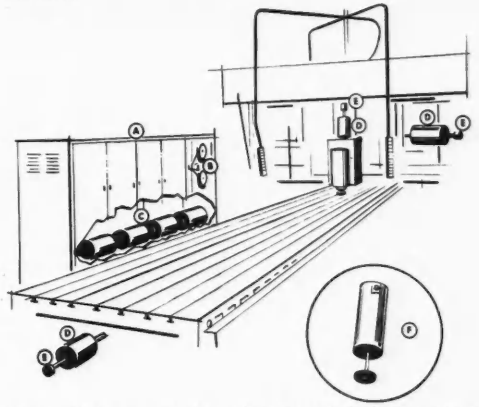

Fig. 3. **Major components of a record-playback control system.**

The principal components of the record-playback control systems are shown in Fig. 3, and comprise floor-mounted enclosures (A), containing all control equipment, including the magnetic tape recorder (B); motor-driven amplidyne generators (C) for supplying direct current to the machine feed motors (D); selsyns (E) for each of the feed motors; and a tracing head (F) which is mounted on a machine tool for making the recording and which, in use, follows the profile of the workpiece accurately made by manual control of the machine, the motions of which are magnetically recorded on the tape.

Available versatile selsyns may be used to measure angular position of the matrix or be rack-geared to measure linear distance with extreme accuracy. The control-transformer types used for record playback are generally accurate to 0·6 deg. or 1 deg., depending on type. Control of the lathe previously mentioned was geared for linear travel of 0·075 in. per selsyn revolution, and if the lathe and tape control had a combined accuracy of 0·001 in., this accuracy would be maintained throughout the 50-in. travel of the lathe bed.

Automatic production of duplicate parts by this control method requires one circuit for making the tape record and another circuit for playing the record back to the machine tool. The same selsyns are used for recording and for playback. Output signals to the machine are identical with those recorded, and electronic feed drives cause the selsyns and motors to rotate in synchrony with the recorded motions. Thus, all machine motions are duplicated in the original sequence and can be repeated thousands of times with great accuracy.

The time period of a controlled machine cycle depends upon the length of tape on a reel and the speed at which the cycle is recorded and played back. Tape on a standard reel of 14-in. diameter can control the operation of a machine during a one-hour cycle. The speed at which a machine can be operated safely should govern the rate of playback. Machine programmes can be altered by cutting out portions of a tape record and by splicing new record sections into it. Magnetic records on the tape retain strength indefinitely during storage of the tape and can be played back as many as 10,000 times without appreciable loss of controlability. Records can be erased easily from the tape and new recordings can be made on it.

GERMANY

Method of Curvature Determination for Curvilinear Cams

By R. BEYER. (From *Industrie-Anzeiger*, Vol. 76, No. 54, July 6, 1954, pp. 27-32, 7 illustrations.)

This article describes methods for the design and production of curves for curvilinear cams. The circles of curvature are determined graphically and by means of formulae for the radius of curvature, so that values of any desired accuracy can be obtained for milling and grinding operations. Numerical examples are given.

IN the design of curvilinear cams, Flocke[1] was the first to indicate how the base circle radius can be determined in such a way as to obtain the required transition angle at the maximum-velocity position of the follower. These methods were further simplified by the author, who also applied them to the design of three-dimensional cams[2, 3, 4]. Additional composite contours, also giving prescribed motion of the follower or rocker arm along the flanks of the curves, were developed by Finkelnburg[5], and set out by the author in a readily usable form for practical design work[6].

The motion imparted to the follower should be determined so as to comply, to a considerable extent, with the prescribed values for permissible velocity and acceleration. If, however, the lift $s = A_oA$, to be plotted on the base circle k_u in Figs. 1a, 1b, or 2, is taken from a displacement diagram (Fig. 3) or a numerical table, the accurate graphical representation of the curve profile of the disc may give rise to difficulties (for instance, because the lift values are frequently very small) and these difficulties may increase still further in the practical production of the master curve required for copy-milling.

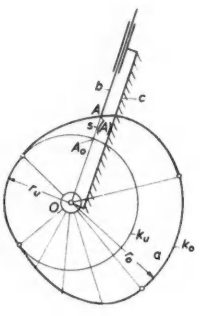

Fig. 1a.

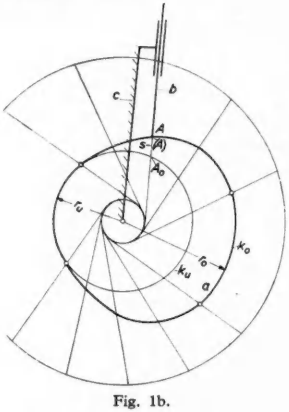

Fig. 1b.

The purpose of this article is, therefore, to provide geometrical and calculation methods for accurate plotting and determination of lift values, particularly at transitions near the base circle k_u or the outer circle k_o. These methods are based on determinations of the radii of curvature.

LAWS OF FOLLOWER MOTION

Follower motion is chosen in accordance with design requirements, taking into account maximum permissible values of velocity and acceleration, and the necessity for obtaining shock-free initial displacement, etc.

Fig. 3a shows as an example a motion based on a parabolic law for the displacement diagram, *viz.*:—

$$s = (2H/T^2) \times t^2 \qquad 0 \leq t \leq T/2 \quad .. \quad (1)$$

where s = displacement [cm], $2H$ = maximum lift [cm], t = time [sec], and T = time period from zero to full lift [sec]. During the first half of the rise, the acceleration is positive with a constant value

$$a = 4H/T^2 \quad .. \quad .. \quad .. \quad (2)$$

whereas, in the second half of the rise, there is a negative acceleration (retardation) of the same magnitude. Maximum velocity is reached at $t = T/2$, its value being

$$v_{max} = v_m = 2H/T \quad .. \quad .. \quad (3)$$

In most types of motion used in practice, the values for maximum velocity and maximum acceleration, v_m and a_m, as well as the acceleration a_M occurring at the time $t = T/2$, can be represented by means of the simple expressions

$$v_m = \xi_m H/T; \; a_m = \eta_m H/T^2; \; a_M = \eta_M H/T^2 \quad (4a, b, c)$$

where the coefficients ξ_m, η_m, and η_M have different constant values for each type of motion considered. In the above example (parabolic law), $\xi_m = 2$, $\eta_m = 4$, and $\eta_M = \pm 4$, the positive sign being for the curve portion ahead of $T/2$ and the negative sign thereafter.

At any position at time t, the motion, therefore, can be represented by

$$v = \xi H/T; \qquad a = \eta H/T^2 \qquad (4a', b')$$

where $\xi = 4t/T$ and $\eta = 4$.

As another example, consider Fig. 3b, for which the motion is given by

$$s = H\,[(t/T) - (1/2\,\pi) \sin (2\,\pi t/T)] \text{ for } 0 \leq t \leq T \quad (5)$$

The acceleration is a sine curve, obtained as

$$a = 2\,\pi\,(H/T^2) \sin (2\,\pi t/T), \quad .. \quad .. \quad (6a)$$

and

$$a_m = 2\,\pi H/T^2, \quad .. \quad .. \quad (6b)$$

whereas the equations for velocity are

$$v = (H/T)\,[1 - \cos (2\,\pi t/T)], \; v_m = 2H/T \; (7a, b)$$

The corresponding coefficients are, therefore, $\xi_m = 2$, $\eta_m = 2\,\pi$, $\eta_M = 0$, so that

$$\xi = 1 - \cos (2\,\pi t/T), \; \eta = 2\,\pi \sin (2\,\pi t/T).$$

DETERMINATION OF RADII OF CURVATURE BY SEMI-GRAPHICAL METHODS

Considering the cam-and-follower system in Fig. 4, it is convenient to denote by A a point representing the follower position and by (A) the corresponding momentary point of contact of the cam. Using this same notation for subscripts, the relations between velocities and accelerations may be written as follows:—

$$v_A = v_{(A)} + v_r; \; a_A = a_{(A)} + a_z + a_r$$
$$= a_{(A)} + a_z + a_{tr} + a_{nr} \quad .. \quad (8a, b)$$

where v_r and a_r are the relative velocity and the relative acceleration, respectively, while a_z is the Coriolis acceleration

$$a_z = 2\,\omega v_r, \quad \text{with} \quad \omega = \omega_{ac} = 2\,\pi/T_{tot} \quad (9a, b)$$

In the above, T_{tot} is the period of one revolution of the cam "a", relative to a stationary point "c". The time T of the ascending motion is a fraction of T_{tot}, which comprises two periods of rest at the full-lift and zero-lift positions, i.e., T_2 and T_4, respectively, the period of rising motion T_1 and the period of descending motion T_3. For the two latter periods, it is convenient to introduce the non-dimensional ratios

$$z_1 = T_{tot}/T_1 \quad \text{and} \quad z_3 = T_{tot}/T_3 \quad (10a, b)$$

The graphical constructions for acceleration, based on eqs. (8) and (9), are carried out as shown in Figs. 4, 6, and 7. The scale for velocities is suitably chosen by drawing in Fig. 4 the vector $v_{(A)}$, representing the driver velocity, equal to the radius $r = O(A)$

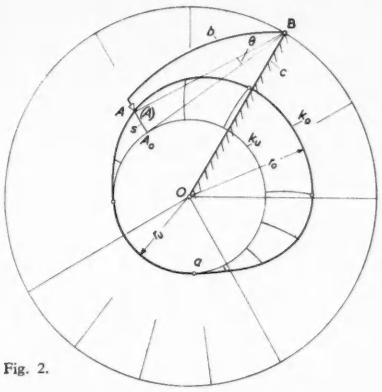

Fig. 2.

$= OA$ from the cam centre to the point of contact. In this way, the scales obtained on the drawing are

$$S_z = \alpha \text{ [cm/m]}, \; S_v = S_z/\omega \text{ [cm/m sec}^{-1}\text{]} \quad \text{and} \quad S_a = S_z/\omega^2 \text{ [cm/m sec}^{-2}\text{]} \qquad .. \quad (10c)$$

With these scales, the Coriolis acceleration a_z is represented in the drawing by the length $2\,v_r$; its direction is that of a vector $v_r^\star$, obtained by rotating the vector v_r of relative velocity through 90° in the direction of $\omega = \omega_{ac}$.

In the case of a centrally located follower (as in Fig. 1a), acceleration occurs in the direction of the follower motion. In rocker-arm systems (Fig. 2), the acceleration has a normal component $a_{n\mathrm{A}}$ and a tangential component $a_{t\mathrm{A}}$ relative to the cam motion (circle about **B** with a radius **B***A*); hence,

$$a_{\mathrm{A}} = a_{n\mathrm{A}} + a_{t\mathrm{A}} \qquad .. \qquad .. \qquad .. \quad (11)$$

Similarly, relative acceleration in both cases (Fig. 1a, b) has a tangential component a_{tr} in the direction of v_r and a normal component a_{nr} perpendicular to v_r, so that

$$a_r = a_{nr} + a_{tr} \qquad .. \qquad .. \qquad .. \quad (12)$$

Eq. (8), after re-arranging the terms, becomes

$$a_{\mathrm{A}} = a_{(\mathrm{A})} + a_z + a_{tr} + a_{nr} \qquad .. \quad (13)$$

$$\text{or} \quad AA_1 = AO + OA' + A'A'' + A''A_1 \quad .. \quad (13a)$$

From the polygon of vectors of eq. (13a), $A''A_1$ is obtained as the normal component of acceleration. If the radius of curvature of the flank of the curve at (A) is denoted by ρ and the corresponding centre of curvature by **A**, so that $\rho = (A)\mathbf{A}$, then ρ may be determined by the relation

$$a_{nr} = v_r^2/\rho, \quad \text{or} \quad \rho = v_r^2/a_{nr} \qquad .. \quad (14)$$

which can either be evaluated numerically or obtained graphically by applying Thales's theorem on the height of triangles (Fig. 5). It should be noted that the acceleration can be determined graphically from $\omega = \omega_{ac}$ = constant, by means of eq. (13a), if the radius of curvature at the flank position is known, as, for instance, in the case of profiles constructed from circular arcs. The expressions for relative motion are not needed in this case, and the problem reduces to that of a cam-and-follower or a rocker-follower system with *O***A** as driving element, **A***A* as a link, and *b* as the follower or oscillating element. Thus, in this instance, the acceleration of the point A as determined from $v_{\mathbf{A}}$ and $b_{\mathbf{A}}$.

If, however, the motion of a follower is based on a specified law of motion (e.g., eq. (1) or eq. (5)), as it is intended to be in this investigation, then the following quantities in eqs. (8a, b), (9a, b), and (13) are known, either as regards their magnitude, line of action, and sense, or only as regards their line of action :—

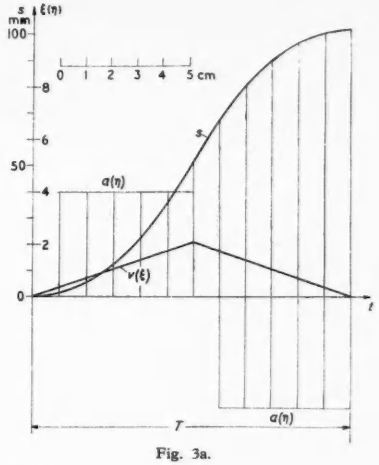

Fig. 3a.

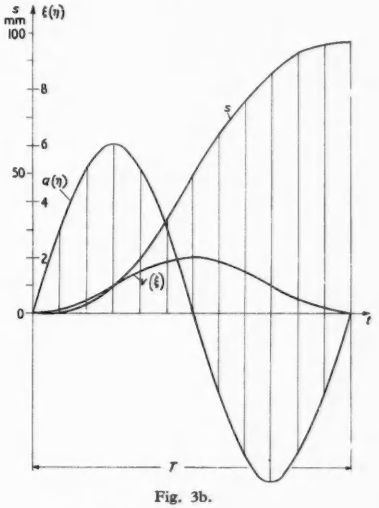

Fig. 3b.

$v_{(\mathrm{A})} = (A)(\bar{A})$ from the given value for $\omega = \omega_{ac}$, the length of $v_{(A)}$ being made equal to $O(\bar{A})$ in the drawing.

$v_{\mathrm{A}} = A\bar{A}$ from the equation of motion in the form $v = \xi H/T$ or from the maximum-velocity positions, where $v_m = \xi_m H/T$.

$a_{(\mathrm{A})} = (A)O$ if ω_{ac} = constant, i.e., if it is assumed that angular acceleration ξ_{ac} is zero.

$a_z = 2\,\omega v_r$ can be determined from eqs. (9), and by means of the scale factor for acceleration already mentioned its length is $2v_r = 2(\bar{A})\bar{A}$, its sense being that of $v_r^\star$.

a_{tr} has the line of action of v_r, while a_{nr} is perpendicular to it.

$a_{t\mathrm{A}}$ from the value $a = \eta H/T^2$ evaluated for the law of motion considered, since in the case of oscillating motion of the rocker arm the acceleration law, e.g., eq. (6a), represents only the tangential acceleration, which, in centrally driven systems, is identical with the follower acceleration.

The basic elements for the graphical determination of the radius of curvature are thus available. Fig. 5 shows details of the construction, assuming that the law of motion is that of eq. (1) at the position $t = T/2$, for a position just ahead of this t-value, since at $T/2$ there is a sudden change in acceleration from $+ a$ to $- a$, owing to the symmetry of the curve (see also Fig. 3a). For acceleration jumps of this kind, it is necessary, therefore, to construct two vector polygons, both extremely close to the position $t = T/2$, but situated on either side of this point.

Details of Graphical Construction

Considering Fig. 4, plot $A(\bar{A}) = v_{(A)} = OA$, calculate the velocity $v = v_A$ from the law of motion and draw this velocity, using the velocity scale, as a vector $A\bar{A}$. Then $\bar{A}(\bar{\bar{A}}) = v_r$. Then, draw $OA' = a_z$ perpendicular to v_r and of length $2v_r$, and plot in the follower direction the acceleration a_A as a vector AA_1, calculated from the law of motion. The parallel through A' to v_r intersects at point A'', the perpendicular to v_r passing through A_1, and this determines the perpendicular component of relative acceleration as a vector $a_{nr} = A''A_1$. On the relative normal Ax of the trajectory, mark $AA_n = A''A_1$, draw $A_n y$ perpendicular to Ax and describe a circle about A with a radius v_r, intersecting $A_n y$ at a point U. The perpendicular to AU through the point U intersects Ax at the required centre of curvature **A**. The circle K_A' of radius **AA** drawn about the centre A should be considered only in its portion situated to the left of A as the circle of curvature of the curve profile.

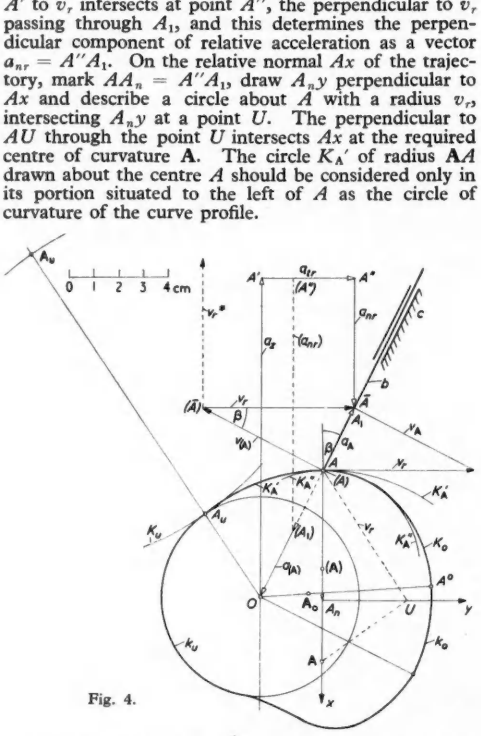

Fig. 4.

For the portion of the curve profile situated to the right of A, plot v_A as a negative acceleration vector $A(A_1)$, so as to obtain $(A'')(A_1)$ as the corresponding vector for (a_{nr}), thus determining (**A**) as the centre of curvature of the circle of curvature K_A''.

Numerical example No. 1 (Fig. 4):—Base circle radius $r_u = 0{\cdot}04$ m, $H = 0{\cdot}03$ m, $\omega_{ac} = 1$ rad/sec, $T_{tot} = 2\pi$, $T = T_{tot}/3$, $z = T_{tot}/T = 3$. Law of motion of eq. (1), i.e., $\xi_m = 2$, $\eta_m = 4$ at the position $r = r_u + (H/2) = 0{\cdot}055$ m, i.e., at the time $t = T/2$. Scale factors :— $S_z = 100$ cm/m, $S_v = 100$ cm/m sec^{-1} and $S_a = 100$ cm/m sec^{-2}; $v = v_A = 2H/T = 0{\cdot}0286$ m/sec, represented by a length of 2·86 cm; $a = a_A = H/T^2 = 0{\cdot}0274$ m/sec^2, represented by 2·74 cm. Results:— $a_{nr} = 0{\cdot}051$ m/sec^2, $v_r = 0{\cdot}062$ m/sec ; hence, $\rho = v_r^2/a_{nr} = 7{\cdot}54$ cm and $(\rho) = 3{\cdot}87$ cm, obtained with $(a_{nr}) = 0{\cdot}0994$ m/sec^2.

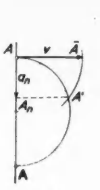

Fig. 5a.

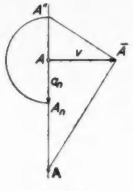

Fig. 5b.

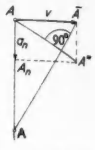

Fig. 5c.

Formulae for Radii and Centres of Curvature

To make results independent of drawing errors, it is desirable to have formulae for the evaluation of various quantities, so as to enable exact data to be given for grinding equipment, etc.

For this purpose, it is advisable to use true values, e.g., velocity in m/sec, so that all scale factors must be eliminated. Evaluating

$$\tan\beta = v/v_{(A)} = vS_v/v_{(A)}S_v,\ \cos\beta = v_{(A)}/v_r, \quad (15a, b)$$

it is seen from the vector polygon for accelerations (positive accelerations) by considering the projection on the relative normal Ax of the trajectory (with $v_A = v$, and $a_A = a$) that

$$a_{nr}S_a = 2\,v_rS_v - [a_{(A)}S_a + aS_a]\cos\beta \quad .. \quad (16)$$

which, on dividing by S_z and taking account of eq. (10c), gives

$$\frac{a_{nr}}{\omega^2} = 2\frac{v_r}{\omega} - \left[\frac{a_{(A)}}{\omega^2} + \frac{a}{\omega^2}\right] \times \frac{v_{(A)}}{v} \quad (16a)$$

By introducing " reduced quantities ", *viz.* :—

Reduced velocities : $q = v/\omega$, $q_r = v_r/\omega$,
$q_{(A)} = v_{(A)}/\omega = r = OA$ .. (17a)

and reduced accelerations : $f = a/\omega^2$, $f_{nr} = a_{nr}/\omega^2$,
$f_{(A)} = a_{(A)}/\omega^2$ .. .. (17b)

all of which have the dimension of length, the entire calculation can be made with " linear " quantities, so that, from eq. (16a) :—

$$f_{nr} = 2\,q_r - [f_{(A)} + f]\,q_{(A)}/q_r \quad .. \quad .. \quad (16b)$$

with $q_r^2 = q_{(A)}^2 = q^2$ .. .. (18)

Fig. 4 shows that $q_{(A)} = f_{(A)} = r$, and, as $\rho = q_r^2/f_{nr}$, the required radius of curvature is given by

$$\rho = q_r^3/[2\,q_r^2 - (r + f)r] \quad .. \quad .. \quad (19)$$

with $q_r^2 = (r^2 + q^2)$, $\cos\beta = q_{(A)}/q_r = r/q_r$ (18a, b)

Thus, eqs. (19) and (18a, b) can be used to calculate the curvature relationships at the position A on the flank of the curve.

For the portion of the cam where the ascending motion occurs with negative acceleration, a minus sign should be prefixed to the reduced acceleration f in eq. (19).

For practical work the following relations are also useful :—

$$q = \xi H/(\omega T) = (\xi z/2\pi) \times H,\ f = \eta H/(\omega^2 T^2) = (\eta z^2/4\pi^2) \times H \quad .. \quad (20a, b)$$

where $z = T_{tot}/T$ and $\omega = 2\pi/T_{tot}$. After calculating the factors

$$\lambda = r/H \quad \text{and} \quad \nu = z/(2\pi\lambda) \quad .. \quad (21a, b)$$

the radius of curvature can be determined as

$$\rho = r\,(1 + \xi^2\nu^2)^{3/2}/[1 + \nu^2\,(2\,\xi^2 - \lambda\eta)] \quad (22)$$

The factor η should have a plus sign for accelerated motion (a and v in the same direction) and a minus sign for retarded motion (a opposite to the direction of v).

Numerical example No. 1 (*continued*):—Centrally-driven follower, and other values as in first part of example 1. From $r = 5{\cdot}5$ cm, $H = 3$ cm, it follows that $\lambda = 5{\cdot}5/3 = 11/6$. With $z = 3$, one obtains $\nu = 9/11\pi$ and $\nu^2 = 0{\cdot}0678$. At the position $t = T/2$, the coefficients have the values $\xi = \xi_m = 2$, and $\eta = \eta_m = 4$; hence, $\xi^2\nu^2 = 0{\cdot}2712$ and $\lambda\eta = 22/3$. From these values, the radius of curvature is obtained as $\rho = 7{\cdot}542$ cm, as previously. At the beginning of the retarded motion, using $\lambda\eta = -22/3$, the corresponding radius of curvature is obtained, i.e., $\rho = 3{\cdot}87$ cm.

The position of the centre of curvature relative to the follower direction is determined by means of eq. (15a), which gives the relations

$$\tan\beta = q/q_{(A)} = \xi z/(2\pi\lambda) = \xi\nu \qquad .. \qquad (23)$$

Thus, in the above example, $\tan\beta = 2 \times 0{\cdot}2604 = 0{\cdot}5208$, and $\beta = 27^\circ 31'$. Particularly simple expressions are obtained for the beginning and end of the rising motion. For these, $\xi = 0$, hence $\beta = 0$, i.e., $q_r = -q_{(A)}$ and $r = r_u$, so that

$$\rho = r_u/(1 - \nu^2\lambda\eta) = r_u/[1 - (z^2H\eta/4\pi^2r_u)] \qquad (24)$$

For retarded motion, η should be used with a minus sign.

For the numerical example, with $z = 3$, $H = 3$ cm, and $r_u = 4$ cm, the values obtained are $\rho_u = 12{\cdot}62$ cm for the radius of curvature at the base circle position, and $\rho_0 = 5{\cdot}035$ cm for the radius of curvature at the stationary position on the outer circle, using $r_0 = 7$ cm and $\eta = -4$. These two special positions have, therefore, the radii of curvature determined by the following relations:—

$$\text{at } r_u\text{: } \rho_u = \frac{r_u}{1 - (z^2H\eta_u/4\pi^2r_u)}; \qquad \text{at } r_o\text{: } \rho_o = \frac{r_o}{1 + (z^2H\eta_o/4\pi^2r_o)} \qquad (25a, b)$$

Curvature on the Flank of a Rocker-type Follower Cam

The conditions for a rocker-type system (e.g., the arrangement shown in Fig. 2 or Fig. 6) are not as simple as for a straight cam-and-follower drive. Considering Fig. 6, and assuming that the values of $v = v_A$ and $a = a_{tA}$ are known from the law of motion used as a basis, the accelerations are determined by the following relations:—

$$a_A = a_{(A)} + a_z + a_{tr} + a_{nr} \qquad .. \qquad .. \qquad (26)$$

$$a_A = a_{tA} + a_{nA} \qquad .. \qquad .. \qquad .. \qquad (27)$$

The graphical construction is indicated in Fig. 6. The angles $\alpha = (\bar{A})\bar{A}A$, $\beta = \bar{A}(\bar{A})A$, and $\gamma = (\bar{A})A\bar{A}$, considered in conjunction with the reduced quantities $q_{(A)} = f_{(A)} = r = OA$, $f_{nA} = q^2/b$, where $b = \mathbf{B}A$, and $f = f_{tA}$ (calculated from the displacement diagram of the law of motion), the necessary equations are obtained for the determination of ρ.

For given values $c = O\mathbf{B}$, $r_u = OA_0$, $b = A_0\mathbf{B} = A\mathbf{B}$ and the prescribed angle of oscillation $\theta = A_0\mathbf{B}A$ at the drive position being investigated, the procedure is as follows:—Calculate from $OA_0 = r_u$, $O\mathbf{B} = c$, $A\mathbf{B} = b$, and θ, the distance $r = OA$; then, from the triangles $O\mathbf{B}A$ and $A(\bar{A})\bar{A}$, calculate

$$\cos\gamma = (c^2 - b^2 - r^2)/(2br), \text{ and } q_r^2 = r^2 + q^2 - 2rq\cos\gamma \qquad .. \qquad (28, 29)$$

$$\sin\alpha = r\sin\gamma/q_r; \quad \sin\beta = q\sin\gamma/q_r; \text{ and } \cos\beta = \sqrt{1 - (q/q_r)^2\sin^2\gamma} \quad (30), (31), (32)$$

These preliminary calculations are made following the same sequence as the reference numbers of the equations.

To determine the normal relative acceleration a_{nr} and its reduced value f_{nr}, the polygon of vectors

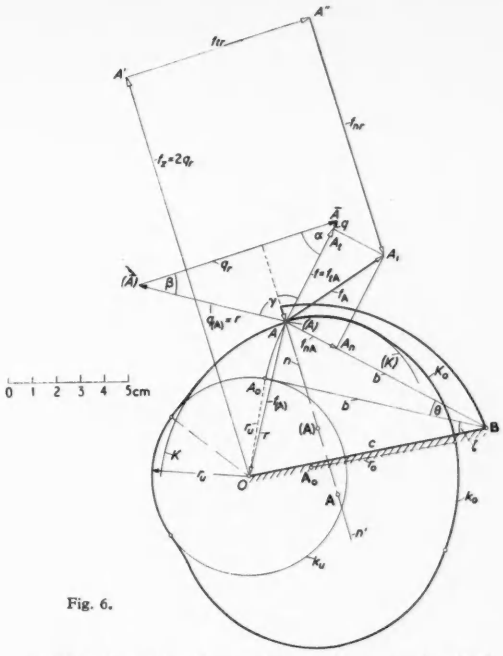

Fig. 6.

$A'OA_tA_1$ is projected onto the relative normal nn' of the trajectory (perpendicular to the relative velocity) and in this way the reduced equation is obtained

$$f_{nr} = 2q_r - r\cos\beta - f\sin\alpha + (q^2/b)\cos\alpha \qquad (33)$$

and therefore $\rho = q_r^2/f_{nr}$ .. .. (34)

It is not advisable to attempt to use a more explicit formula for the radius of curvature, as the expressions then become fairly involved. As in the case of the straight cam-and-follower drive, however, the conditions at the beginning and end of the rising motion are represented by fairly simple formulae. Assuming that the beginning of the rise is such that $q = O$, then $q_r = q_{(A)} = r_u$, and $t = 0$, the resulting formula is

$$\rho_u = r_u/[1 - (f_u/r_u)\sin\gamma_u] = r_u/[1 - (\eta z^2/4\pi^2r_u)H\sin\gamma_u] \qquad .. \qquad (35)$$

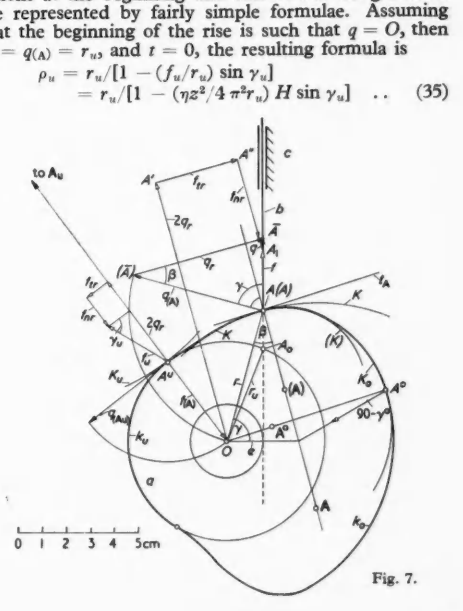

Fig. 7.

and similarly for the end of the ascending motion (with retardation), at the position for which $r = r_o$ is reached, while γ has the value γ_o

$$\rho_o = r_o/[1 + (f_o/r_o) \sin \gamma_o] = r_o/[1 + (\eta z^2/4\,\pi^2 r_o)\, H \sin \gamma_o] \quad .. \quad (36)$$

The transition to the centrally located drive is obtained with $c = b = \infty$ and the angles γ_u and γ_o both equal to 90°. Then eq. (36) reduces to eq. (25).

Offset-type Followers

In the case of offset-type followers (Fig. 7), if $c = b + e$ is introduced into eq. (28), it follows that

$$\cos \gamma = e/r + e^2/2\,br + r/2\,b$$

and with $b \to \infty$, the limiting case

$$\cos \gamma = e/r \quad .. \quad .. \quad .. \quad (37)$$

With the aid of the equation

$$q_r^2 = r^2 + q^2 - 2\,eq,$$

$$\sin \alpha = \frac{\sqrt{r^2 - e^2}}{q_r}; \quad \cos \alpha = \frac{q - e}{q_r};$$

$$\cos \beta = \frac{r^2 - qe}{q_r\, r} \quad .. \quad (38a, b, c)$$

and, according to eqs. (33) and (34),

$$\rho = \frac{{q_r}^3}{2\,{q_r}^2 - r^2 + qe - f\sqrt{r^2 - e^2}} \quad .. \quad (39)$$

For the special case of $q = 0$,

$$\rho_u = \frac{r_u}{1 - (f_u/r_u) \sin \gamma_u};$$

$$\rho_o = \frac{r_o}{1 + (f_o/r_o) \sin \gamma_o} \quad .. \quad (40a, b)$$

or

$$\rho_u = \frac{r_u}{1 - \dfrac{\eta_u z^2\, H\sqrt{{r_u}^2 - e^2}}{4\,\pi^2\,{r_u}^2}} \quad .. \quad .. \quad (40c)$$

$$\rho_o = \frac{r_o}{1 + \dfrac{\eta_o z^2\, H\sqrt{{r_o}^2 - e^2}}{4\,\pi^2\,{r_o}^2}} \quad .. \quad .. \quad (40d)$$

For $e = 0$, eqs. (40c) and (40d) are again transformed into eqs. (25).

Numerical example No. 2 (Fig. 7):—It is required to design the rising portion of the flank contour of a cam with an offset follower, in accordance with the following specification:—Time factor $T_{tot}/T = z = 3$; base circle radius $r_u = 40$ mm, and eccentricity $e = 15$ mm (already determined from the required transition angles at the approach positions); law of motion of eqs. (1) to (3), with a stroke $H = 30$ mm. The radii of curvature are to be calculated for the positions $t = 0$, $t = T/2$ and $t = T$ (full-lift position), as well as their corresponding centres.

(a) Beginning of rise:—From the law of motion, the following values are determined:—$v_A = 0$, $\xi_M = 0$, $q = v/\omega = 0$, $a_A = 4\,H/T^2$; hence, $\eta_u = 4$, and from eq. (20b) the "reduced acceleration" of the follower is $f_u = 27/\pi^2 = 2{\cdot}735$ cm. Furthermore, $q_r = q_{(A)} = r_u = 4$ cm, $\beta = 0$, and, from eq. (39), $\rho_u = 10{\cdot}924$ cm.

(b) End of rise:—The outer radius is calculated from ${r_o}^2 = e^2 + [\sqrt{{r_u}^2 - e^2} + H]^2$, which gives $r_o = 6{\cdot}874$ cm. As $q_r = r_o$ and $f_o = -2{\cdot}735$ cm, it follows from eq. (39) that $\rho_o = 4{\cdot}951$ cm. The centres of curvature $\mathbf{A}_u$ and $\mathbf{A}^o$ for (a) and (b) are situated on the lines OA^u and OA^o.

(c) Mid-position $t = T/2$ (before the acceleration jump):—From eq. (37), $\cos\gamma = e/r$, with $r^2 = e^2 + [\sqrt{{r_u}^2 - e^2} + (H/2)]^2$; hence, $r = 5{\cdot}421$ cm; also $\xi = 2$, so that $q = 9/\pi = 2{\cdot}865$, $\eta = 4$, $f = 27/\pi^2 = +2{\cdot}735$, and $q_r = 5{\cdot}835$; from eq. (38c) $\beta = 30°\,46'$, and from eq. (39) $\rho = \mathbf{A}A = 8{\cdot}367$ cm, with centre of curvature at $\mathbf{A}$.

(d) Position $t = T/2$ (after the acceleration jump):—Evaluation as under (c), using, however, a minus sign for acceleration, i.e., $f = -2{\cdot}735$. Results:—$(\rho) = A(\mathbf{A}) = 3{\cdot}310$ cm, with centre of curvature at $(\mathbf{A})$.

Simplification of Design Procedure for Rocker-type Follower Cams

The design procedure for cam systems of this type (Fig. 6) can be simplified as follows:—

Evaluate $\sigma = (c + b + r_u)/2$ and determine the angle ζ from

$$\tan(\zeta/2) = \sqrt{(\sigma - b)(\sigma - c)/[\sigma(\sigma - r_u)]} \quad (41)$$

Next, from the prescribed or chosen value for the angle of lift θ, calculate the radius $r = OA$ by means of the relation

$$r^2 = b^2 + c^2 - 2\,bc \cos(\zeta + \theta) \quad .. \quad (42)$$

Furthermore, evaluate angle γ, q_r, $\sin\alpha$, and $\sin\beta$ from eqs. (28) to (31). Taking into account eqs. (33) and (34) and using $\cos\beta = \sqrt{1 - \sin^2\beta}$, the explicit formula for the radius of curvature is then obtained as

$$\rho = \frac{(r^2 + q^2 - 2\,rq\cos\gamma)^{3/2}}{r^2 + 2q^2 - 3rq\cos\gamma + (q^2/b)(q - r\cos\gamma) \mp fr\sin\gamma} \quad (43)$$

and the position of the relative normal nn' of the trajectory is given by

$$\sin\beta = q\sin\gamma/\sqrt{r^2 + q^2 - 2\,qr\cos\gamma} \quad .. \quad (44)$$

In eq. (43), the term $fr\sin\gamma$ has the negative sign for acceleration from A (acceleration vector in the direction of velocity); for retardation, the positive sign should be used. Eqs. (43) and (44) cover all particular cases, including that of the straight cam-and-follower system.

Special conditions occur at cam or follower positions corresponding to zero tangential acceleration, e.g., when using the law of motion of eq. (5) at the positions $t = 0$, $t = T/2$, and $t = T$. For these cases, $f = 0$ in eq. (43). Also, on approaching the base circle k_u or the outer circle k_o, it should be noted that $q = 0$, and hence $\rho_u = r_u$ or $\rho_o = r_o$.

Numerical example No. 3:—It is required to determine the ascending flank of a rocker-type follower cam and the curvature values for the final grinding of the individual circular-arc sectors. The values given are:—Distance between shaft centres $c = 100$ mm; effective length of the swinging link $b = 90$ mm; base circle radius (determined from specified transition angle) $r_u = 40$ mm; angle of lift $\theta = 30°$; time ratio $T_{tot}/T = 4$; law of motion of cam such as to obtain acceleration values of zero at the beginning and end of the ascending motion; hence, the law of motion in eq. (5) is used, with the values $f = 0$ at $t = 0$, $t = T/2$, and $t = T$.

From eqs. (41) and (42), the mid-position $t = T/2$ corresponds to $\zeta = 23°\,33'\,40''$, and, with angle of lift $= \theta/2 = 15°$, $r = 6{\cdot}346$ cm, and eq. (20a), with $\xi = 2$, $z = 4$, and $H = 9\,\pi/6$, gives $q = 6$ cm, so that, from eqs. (28) and (29), it follows that $\gamma = 100°\,43'\,43''$ and $q_r = 9{\cdot}51$ cm. The position of the relative normal of the trajectory is determined by means of eqs. (31) or (44), with $\beta = 38°\,18'\,47''$, and from eq. (30), with,

$\alpha = 40^\circ\ 57'\ 30''$. Finally, from eqs. (33) and (34), where $f = 0$ in this instance, $f_{nT} = 17{\cdot}063$ cm and $\rho = 5{\cdot}301$ cm. Eq. (43) could also be used to determine the radius of curvature ρ.

For the beginning and end of the rise, as $q = 0$ and $f = 0$, the radii of curvature are $\rho_u = r_u = 4$ cm and $\rho_o = r_o = 8{\cdot}605$ cm.

Furthermore, if the circles of curvature with their corresponding radii are plotted for the times $t = T/4$ and $t = 3\ T/4$, it can be seen that this set of circles of curvature gives a very good approximation for the ascending flank. For milling or grinding, the operator would also require an indication of the co-ordinates of the centres of curvature relative to a suitably chosen reference system. These values can easily be calculated by means of the angle β from eq. (44).

General Remarks

The procedure described above shows how the circles of curvature can be determined exactly for the flank contours of two-dimensional straight or rocker-type cam-and-follower systems, so as to permit the adjustment of a co-ordinate locator to accurate datum points. This procedure opens up new possibilities for the workshop production of such curvilinear gears, as well as for the milling and grinding of the master cam required for copy-milling. The laws of motion, such as, for instance, that given in eq. (5), frequently require very small lift values at the beginning and end of the rise, which cannot be determined with the required accuracy by purely graphical construction in the design stage, or by hand-finishing in practice. This requirement is particularly important in the case of high-speed cams.

By selecting a number of intermediate positions, the accuracy of this grinding or milling process can be increased as required, and, in addition, the limit angles for each arc of circle of curvature can be indicated to the operator. At an acceleration jump, e.g., the discontinuity in eq. (1), it should be noted again that this cam position corresponds to two different circles of curvature, extremely close to, and on either side of, the point considered.

In the case of roller followers, the roller with a radius R describes a " roller curve " on the cam contour. The roller centre A (which is the centre of curvature of the roller curve), relative to the cam a, follows the circle of curvature with the calculated radius. The centre of curvature $\mathbf{A}$ of the cam contour $\bar{a}$ generated from the roller curve coincides with the centre of curvature $\mathbf{A}$ of the curve described by A on a. The centre of curvature $\bar{\rho}$ of the roller curve, in the present case (with external contact), is therefore equal to the difference between ρ and R, i.e. $\bar{\rho} = \rho - R$.

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SWITZERLAND

A Survey of Corrosion Inhibitors

By A. Bukowiecki.

(From " *Schweizer Archiv*," Vol. 20, No. 6, June 1954, pp. 169-186, 8 illustrations.)

Inhibitors added to corrosive liquids in small quantities, usually 0·01 to 0·1% and seldom above 1%, reduce or even prevent corrosive attack on metals. A survey is given in this article of the most important properties of inhibitors, and of their action according to the modern theory of corrosion. Only inhibitors intentionally added to corrosive liquids are included. Naturally occurring inhibitors (hardening agents in natural water, or certain anti-corrosion constituents of oils), as well as agents added to materials which are in themselves protective, have been excluded.

(A) INHIBITORS FOR NEARLY NEUTRAL AQUEOUS SOLUTIONS

Corrosion of metals in nearly neutral aqueous solutions with access of air gives rise to the following important phenomena :—

(a) The corrosive liquid removes the oxide film formed at the metal surface. At the same time, oxygen dissolved in the liquid from the surrounding air reacts with the metal to form a new oxide film, which is again removed by corrosion, and so on. This removal may be caused by physical detachment, if liquid penetrates to the bare metal through pores and attacks the metal in spite of the film. It may also be caused by chemical dissolution of the film in the liquid. Hence, metals and alloys with sufficiently dense and chemically resistant oxide films e.g., aluminium and stainless steel, exhibit considerable resistance to corrosion by many neutral aqueous solutions.

(b) At bare metal surfaces in contact with the liquid, e.g., at the base of pores or gaps in the film, metal ions are liberated from the metal in an " anodic " (corrosive) reaction and combine with anions absorbed from the liquid. If these combinations are difficult to dissolve, they may remain at the surface, closing the pores and impeding further attack; if they are removed by decomposition in the liquid, corrosion continues.

(c) The electrons freed by the anodic reaction penetrate the metal and re-appear at certain " cathodic " spots on the surface, where they join hydrogen ions from the liquid. The resulting hydrogen at once re-combines with the dissolved oxygen to form water. This cathodic reaction occurs mainly at points most accessible to oxygen, i.e., at the outer surface of the thin oxide film, which cannot impede the passage of electrons.

All these three phenomena can be suitably influenced by inhibitors, which therefore may be classified according to the mechanism of their action :—

(1) Inhibitors Favouring the Formation of Oxide Films

Sodium chromate (Na_2CrO_4).

Sodium bichromate ($Na_2Cr_2O_7$).

Sodium nitrite ($NaNO_2$).

These " oxidising " salts increase the concentration of oxidising agents at the metal surface, so that oxide films are formed more quickly, and are thicker and denser. With certain metals, particularly iron, they are able to inhibit corrosion completely. Additions of the

chromate directly to the surface of iron inhibit corrosion even when the solution is free of oxygen. Both the chromate and nitrite are called passivators[1]. Isotope tests[2] have shown that iron, " passivated " with chromate is covered with adsorbed chromium compounds which cannot be washed out in water and which preferentially adhere to rusty spots.

If the additions of inhibitor are too small for complete protection, the reduced attack may cause typical pitting. Very small bare " anodes," mainly inclusions, cracks, etc. in the oxide film, form local galvanic cells with the large film-covered " cathodic " surfaces and are thus exposed to concentrated local attack (Fig. 1). Chlorides in the water are deleterious to the oxide film and impair the action of chromates, so that additions must increase with increasing chloride content[5] (Fig. 1). The protection of iron is not much influenced by small changes in pH-value but is destroyed in strongly acid solutions. An increase in temperature reduces the efficiency gradually; adsorption of inhibiting ions to the metal is slowed down; so, too, is the formation of oxide film[2].

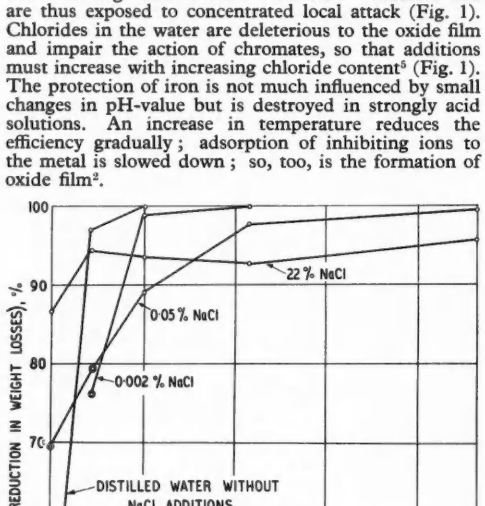

Fig. 1. **Effect of small chromate additions on the corrosion of iron in solutions of various chloride concentrations.**
Temperature, 95° C; duration, 14 days; liquid agitated. Complete protection requires 0·5 grams/litre in distilled water, 1 gr/l in 0·002% NaCl solution, 2 gr/l in 0·05% NaCl solution. Complete protection is impossible with 22% NaCl solution.

Certain non-ferrous metals, e.g., zinc and lead, cannot be protected by nitrites because their oxide films are porous and unstable. Chromates protect these metals by filling the pores with zinc or lead chromates, which are difficult to dissolve (Table I). However, as zinc and lead chromates are soluble in weak acids and the metals are vulnerable to alkalis, chromate-inhibited liquids in contact with zinc and lead should be kept between pH 7·5 and 8·5. Use of nitrites and chromates with alloys may be dangerous. If iron-zinc or iron-lead combinations are in contact with nitrited liquids, the iron will be passivated and will act as a cathode, but the alloyed element will form the anode and will be intensively corroded. Chromates have a similar effect, if additions are too small or if the liquid becomes slightly acid[3]. Even tin-lead soft solders are attacked by nitrited solutions.

TABLE I.—EFFECT OF INHIBITOR ON CORROSION OF CLEANED METAL PLATES HALF DIPPED INTO WATER AT ROOM TEMPERATURE.

Test Liquids	Grams/m²				
	Iron	Zinc	Aluminium	Lead	Copper
Distilled Water ..	14·9	6·3	0	42·2	0·9
Do. + 5 gr/litre K_2CrO_4	0	0	0	1·1	0
Do. + 5 gr/litre $NaNO_2$	0	8·5	0	15·6	0

Chromates must be added in larger quantities than required for short-time protection, because they are used up by reaction with the metal (oxide films still change, though more slowly); chlorides accelerate this consumption. If corrosion has already started, part of the chromates is adsorbed into the rust, so that an initial extra amount is required. Nevertheless, chromate additions of 0·5 gr/l suffice for industrial plant, even with old rust deposits, provided that water temperature remains below 65° C.

The attack of hot concentrated chloride solution on iron can be mitigated by chromates; the intensive corrosion of aluminium in these solutions is beyond their influence. Installations of iron, galvanised iron, and brass, used for 20 to 25% NaCl or $CaCl_2$ brines at relatively low temperatures, can be fairly well protected by chromates (3·5 gr/l for NACl-brine, 1·7 gr/l for $CaCl_2$-brine)[4]. If an organic anti-freeze agent is added, chromate may react with its alcoholic constituents and be used up, whereas nitrites, which are much weaker oxidising agents, do not react with organic anti-freeze[4].

(2) INHIBITORS SEALING THE PORES IN OXIDE FILMS

Mixtures of primary and secondary sodium orthophosphates (NaH_2PO_4 *and* Na_2HPO_4), *yielding neutral or slightly alkaline solutions.*

Sodium carbonate (Na_2CO_3).

Borax ($Na_2B_4O_7$).

Sodium benzoate ($NaC_7H_5O_2$).

All these inhibitors combine with the anodic metal ions to form barely soluble salts deposited in the pores of the oxide film. Alkalinity is an advantage in the case of iron, which is in general protected by strong bases; it is a disadvantage in the case of alkali-sensitive non-ferrous metals, especially aluminium. These inhibitors are usually less powerful than film-forming inhibitors and must be added in concentrations ten times greater. They are efficient only if the solution contains dissolved oxygen. Even strong alkalinity does not prevent corrosion of iron when oxygen is absent, whilst a nearly neutral solution with oxygen protects iron completely. Without oxygen, corrosion continues at a constant rate (ferrophosphates alone do not protect iron efficiently); with oxygen it is halted, because the oxide film forms continuously as soon as sufficient insoluble ferrophosphates have been deposited in its pores[6] (Fig. 2).

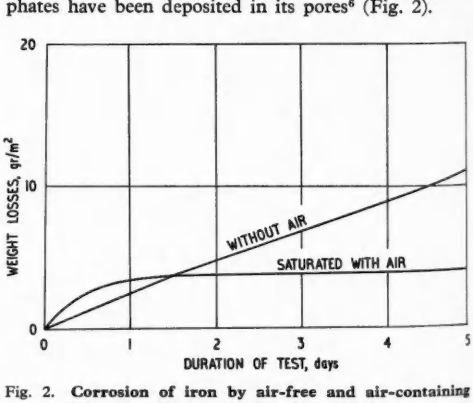

Fig. 2. **Corrosion of iron by air-free and air-containing 0·1-mol sodium orthophosphate solutions.**
pH = 7·0; temperature = 25° C.

With the exception of sodium benzoate, these inhibitors also cause local pitting, if present in insufficient concentration. Chloridic solutions again reduce efficiency. In contrast with chromates and nitrites, these inhibitors are non-toxic; sodium benzoate, for instance, is used for the impregnation of packing paper. A novel recommendation is the addition of sodium nitrite and sodium benzoate to ethylene glycol antifreeze agents for car radiators; the former prevents corrosion of the metal, the latter protects soft-soldered joints against the nitrite. The better known triethanolamine phosphates have the advantage of good solubility, even in concentrated glycol, but attack copper and its alloys, so that another inhibiting agent, sodium mercaptobenzothiazole, must be added.

(3) CATHODIC INHIBITORS

Calcium carbonate deposits improved by polymeric sodium phosphates[7].

These inhibitors form deposits at the cathodic spots, thus reducing the intensity of attack, so that weight losses correspond only to the very small amount of oxygen reaching the bare anodic spots. For instance, calcium bicarbonate in water combines with cathodic hydroxyl ions and forms nearly insoluble, but loose, calcium carbonate deposits, which, together with the products of corrosion, form layers of appreciable thickness and then reduce corrosion. The build-up is very slow; new steel pipes for hard water need several years before the corrosion rate decreases noticeably. Small additions of polymeric sodium metaphosphate, tetraphosphate, or tripolyphosphate to the water vastly improve and accelerate protection by deposition of long-chain molecules. The metaphosphate (under the trade name of " Calgon ") is mostly used as an inhibitor.

These polymeric phosphates are primarily intended to prevent calcium-rich precipitation from hard water but are also so strongly adsorbed into the cathodic, initially very thin, calcium carbonate layers that appreciable protection against corrosion is achieved. For instance, this has been observed with concentrations of " Calgon " as low as 0·0005 to 0·001 gr/l. Inhibition will be pronounced in water containing calcium ions, but very weak in distilled water. The optimum concentration is determined by a definite ratio CaP_2O_5, which varies with the hardness of the water, so that maximum protection is difficult when hardness varies. Excessive additions of " Calgon " even lead to increased corrosion, because easily soluble compounds are formed by combination of excess phosphates with the corroding metal[8] (Fig. 3). Polymeric phosphates protect not only iron but also to a large extent zinc, and to some extent lead. Increasing temperatures slowly decrease their efficiency (breaking up of polymers) but chlorides do not affect inhibition; even corrosion by concentrated NaCl solutions may be stopped, provided that calcium ions are present. However, adsorption of phosphates into the $CaCO_3$ films is slow, so that protection may fail in stagnant or slightly agitated liquids. Insufficient additions produce pronounced local pitting in iron[9]. Since pitting is due to a concentration of corrosion on a reduced number and extent of anodic spots, a merely cathodic inhibition cannot by itself cause pitting. Hence, the phosphates also act on anodic spots, chemically as well as physically, by penetration into some of the pores.

(4) INHIBITORS FORMING GEL DEPOSITS

Water-soluble sodium silicates.

Organic colloids.

Sodium silicates, forming meta-and di-silicate ions in aqueous solutions but also present as colloidal silicic acid, inhibit corrosion in two ways :—(a) Silicate ions and hydroxyl ions combine with the metal to form only slightly soluble silicates and hydroxides which seal the pores of the oxide film. (b) The colloids and the metal ions form gels which are rich in silicic acid;

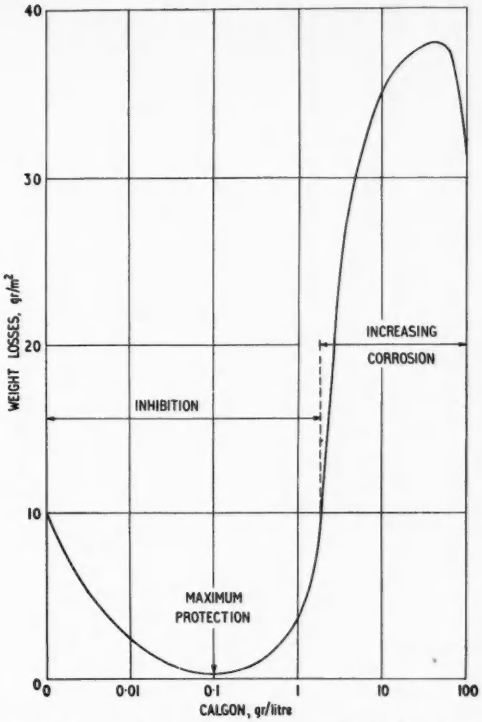

Fig. 3. **Corrosion of iron in agitated tap water with various additions of " Calgon."**

these gels impede the access of corrosion agents and thus considerably reduce attack, even at areas already strongly corroded. Consequently, insufficient additions do not lead to pitting, in spite of the anodic action (a). Very small quantities of these inhibitors therefore restrict, without localising, intensive corrosion, and are used for boiler feedwater and similar purposes. Zinc and lead are also protected. Increasing temperatures accelerate gel formation and improve inhibition. Mixed with other inhibitors, e.g., chromates, they reduce the danger of local attack. Chromate with sodium silicate (waterglass) is recommended for Al-Cu alloys, which otherwise are difficult to protect[4].

Adsorption of colloidal particles and formation of gels also occur with organic colloids (e.g., gelatine, albumin, tannin, dextrin, starch, and agar-agar) used as inhibitors. However, deposition of a sufficiently dense layer is less likely, so that corrosion is not stopped completely. The inhibiting effect of small additions is often slight, and it is possible that these organic colloids will become oxidised and ineffective in time.

(*To be concluded*)

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SOUTH AFRICA

Photoelectric Apparatus for Assessing Dust Samples

By D. G. BEADLE. (From *Journal of the Chemical, Metallurgical & Mining Society of South Africa*, Vol. 55, No. 2, August 1954, pp. 30-39, 8 illustrations.)

Designed specifically for assessing samples taken with the modified thermal precipitator, which collects dust particles of various sizes in proportion to their lung retention, the photoelectric apparatus described in this article has several advantages over the usual microscope method of counting dust samples.

THE method of assessing a dust sample by counting under a microscope the number of particles present has the following disadvantages :—

(a) The process is laborious and time-consuming.
(b) Observers require lengthy training and considerable experience before they become proficient.
(c) Results are subject to variations, owing to the human factor.
(d) Usually only a small fraction of the whole sample can be examined, and this may not be representative of the whole sample. This leads to unavoidable errors in the result.
(e) There is considerable doubt whether particle number is an accurate indication of the danger to health of the dust.

For assessing dust samples, there is a need for a rapid, consistent, and simple method which eliminates the human factor and which measures a property of the dust closely related to its danger to health. In a previous paper*, it was suggested that the property which should be measured was basically the surface area of the particles caught in the lung, with some over-estimation of the surface area of the particles in the region of $\frac{1}{4}$ to 2 microns in diameter, and under-estimation of the particles below approximately $\frac{1}{2}$ micron in diameter.

The modified thermal precipitator was designed to collect dust particles of various sizes approximately in proportion to their retention in the human lung ; parallel with the development of the modified thermal precipitator, a photoelectric apparatus was designed and constructed to enable the samples to be measured rapidly and conveniently. It was expected that an instrument measuring the light extinguished from a beam passing through the dust sample would provide a reading closely related to the surface area of the particles, but with the desired over-estimation of the particles below about 2 microns in diameter.

The idea of using photoelectric methods to assess dust samples is not original. Many workers have developed such instruments, but all have attempted to interpret the photoelectric reading in terms of a number count, and this has lead to considerable uncertainty in the interpretation of the data. With the exception of Watson and Hounam's P.R.U. densitometer, none of the instruments developed by these workers has found general acceptance. The P.R.U. densitometer is used only for measuring comparatively heavy deposits obtained on filter paper ; this is a collecting material which cannot be ignited before examination, and is therefore unsuitable for use on Witwatersrand gold mines.

BASIC THEORY OF THE PHOTOELECTRIC APPARATUS

When a beam of light passes through a collection of particles, some of the light is reflected, some is scattered, and some may be absorbed by the particles. The result is that the light in the transmitted beam is attenuated.

When the particles are large, compared with the wavelength of the light used, the light extinguished is proportional to their projected surface area. As the particle size decreases and approaches the wavelength of the light, the light extinguished per unit surface area increases. When the particle size is small, compared with the wavelength of the light, the Rayleigh law of scattering applies, i.e., the scatter is proportional to the sixth power of the diameter, and the light extinguished per unit surface area falls rapidly to nearly zero.

Since visible light has a mean wavelength of approximately 0·5 micron, this implies that an apparatus measuring the extinction of visible light would give a measurement of the surface area of the particles, with an over-estimation of the surface area of particles slightly larger than the wavelength of light (i.e., particles of the order of 1 micron in diameter) and with a rapidly increasing under-estimation of the surface area of particles below 0·5 micron. As has been shown in a previous paper*, this would reproduce qualitatively the toxicity of silica particles. At present, there is insufficient pathological evidence to place this relationship on a quantitative basis. This relationship forms the basis of the apparatus described below.

To make use of the laws of scatter, the particles must be homogeneous in composition, size, and shape, their refractive index must be known, the wavelength of the light used must be known, and the geometry of the design of the apparatus for measuring the amount of extinction must be specified.

These requirements regarding the particles do not hold in the case of mine dusts, and there appeared to be no possibility of calculating the design and performance of an instrument with predetermined measuring characteristics. Instead, various experimental designs were tried on an optical bench, their characteristics measured, and a final design constructed in a form suitable for use by mining personnel. The actual property of the dust, measured in this apparatus, was then determined in a series of calibration tests.

DESCRIPTION OF THE PHOTOELECTRIC APPARATUS

The basic construction of the apparatus is shown diagrammatically in Fig. 1. The apparatus is built on a heavy baseplate with light-tight thin metal sides and a lid which is screwed on after optical adjustments have been made. All internal metal surfaces are painted matte black, to minimise stray light. The apparatus measures 24 in. × 15 in. × 8 in. in height.

The lamp (*A*) has a coiled vertical filament, approximately $\frac{3}{8}$ in. high and 0·04 in. wide. It is mounted on a base which can be moved in three dimensions or tilted so that, when a lamp is changed, adjustment can be made to compensate for slight differences in the position of the filament. The lamp, which must be fed from a stable supply, is rated at 8·5 V, 35 W, but is under-run slightly, to increase its life. The circuit includes a 3-ohm, 10-ampere rheostat and an ammeter. The lamp housing includes a louvred ventilator.

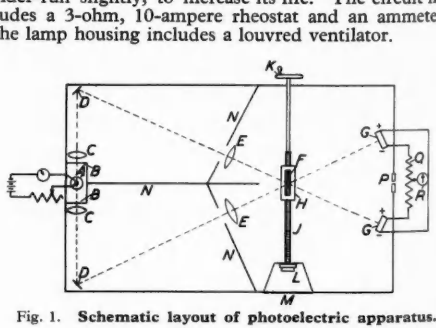

Fig. 1. **Schematic layout of photoelectric apparatus.**

*D. G. BEADLE : " The properties of a dust sample which should be measured." *J. Chem. Met. Min. Soc. S.A.*, Vol. 55, August 1954, p. 25.

Two identical beams of light from the lamp pass through the apparatus. Adjustable diaphragms (*B*) determine the dimensions of the beams, which then pass through lenses (*C*) of 2-in. focal length, and are reflected by mirrors (*D*) and re-focused by lenses (*E*) of 4-in. focal length. The beams pass close to each other through the glass slide (*F*), which carries the dust samples, and fall onto barrier-layer photocells (*G*).

The glass slide is carried on a holder (*H*), which is moved laterally by a screwed rod (*J*) and crank (*K*). The slide-holder (*H*) is designed to travel out into a compartment (*L*) when the slide is to be changed. This compartment has a lightproof door (*M*). Inside the box are baffles (*N*), to reduce stray light. A small observation port (*P*) enables the glass slide to be observed.

The two photocells are connected in opposition through a 25-ohm potentiometer (*Q*) and a pointer-type galvanometer (*R*), which has a sensitivity of 4 mm/μA, a resistance of approximately 150 ohms, and a periodic time of $2\frac{1}{4}$ sec. It has a centre zero.

The illumination at the dust deposit must be evenly distributed. This is achieved by the Kohler system of illumination, i.e., lens (*C*) throws an image of the lamp filament onto lens (*E*), and lens (*E*) throws an image of the surface of lens (*C*) onto the slide (*F*). The dimensions of the lamp filament and diaphragms (*B*) are such that, taken with the other dimensions of the apparatus, the image of diaphragm (*B*) thrown on the dust slide is the same height as, and slightly wider than, the dust samples on the slide.

Each light beam diverges after passing through the slide, and produces an out-of-focus image of the filament on the photoelectric cell. Each photocell is covered by a mask of a size such that this image fills the exposed surface of the photocell, and therefore any light scattered from the beam by the dust particles on the slide falls outside the photocell surface. Thus, the electrical output of the photocell is reduced in proportion to the amount of light scattered or absorbed by the particles in the dust sample.

Matched pairs of photocells were selected, but, despite this and the general symmetry of the two beams, it was found necessary to incorporate the potentiometer, to enable the galvanometer reading to be brought to zero when both beams of light traverse a blank portion of the glass slide. There are day-to-day variations in the galvanometer zero reading, as well as a gradual drift during a day. This is adjusted by resetting the potentiometer. The sensitivity of the apparatus, i.e., the deflection of the galvanometer for a given amount of dust, can be controlled by adjusting the size of diaphragms (*B*), and by varying the brightness of the lamp.

Two beams of light are used ; this compensates to a large extent for slight variations in lamp brightness during a series of measurements, and is also necessary because the surfaces of the glass slide often scatter as much light as the dust particles. When a measurement is made, one beam of light passes through the dust sample and glass slide, while the other passes only through the glass slide nearby. Variations from average in the reflectivity of the glass and in the amount of absorbtion of light in the glass are thus automatically compensated for, and the difference in the intensity of the two light beams is therefore due to the light scattered or absorbed by the dust particles.

Operation of the Apparatus

The lamp is switched on at least 15 minutes before it is desired to measure a sample. This allows the photocells to reach a fairly stable output, after which drift is greatly reduced. The lamp current is adjusted to 4·0 A.

The glass slide is inserted into the slide holder and, by turning crank (*K*), is brought into a position where both beams of light traverse portions of the slide which have no dust deposited on them. The potentiometer is then adjusted to bring the galvanometer reading to zero.

The slide is then moved until the first dust sample is seen through the observation port to be in the centre of one of the light beams ; this position is judged by observation, and the slide is then moved slowly from side to side until the galvanometer reading is a maximum ; this reading is noted. The same dust sample is then brought into the other beam and the process repeated, with a galvanometer reading being obtained on the other side of zero. The two galvanometer readings added together give the assessment of the dust sample. The next dust sample on the slide is then measured in the same way. Each reading takes about 10 seconds to make, compared with the 10 to 20 minutes normally required to count a thermal precipitator sample.

An alternative method of making the measurement is to use the potentiometer to bring the galvanometer pointer to zero when the dust sample is in one beam. This " null " method appears to have no advantages over the method described above, and a longer time is needed to obtain the readings.

The various sources of error in microscope methods of counting dust samples lead to an overall error, with experienced observers, of the order of 10%. The consistency of readings on the photoelectric apparatus is of the order of 1%.

Calibration of the Apparatus

It was important to determine how the measurements in this apparatus were related to the surface area of the particles in the dust sample. It was also desired to know if the readings were dependent to any appreciable extent on the material from which the dust was produced ; it was possible that the refractive index of the particles might affect the results significantly.

It is not practicable to produce dust clouds of, say, quartz, in which all the particles are of uniform size. All that can be done is to produce clouds which are generally fine or generally coarse.

Samples of pure quartz dust of widely differing size distribution and number concentration were collected by a modified thermal precipitator and evaluated in the apparatus. Four or five measurements were made of each sample, and these invariably agreed to better than 1%. The dust samples were then examined under the microscope and the number and size of particles estimated as in the standard method of dust-counting. About 1000 particles were counted and measured in each sample.

The total projected surface area of all the particles in the sample was then calculated from these microscope measurements. It should be noted here that, although the microscope method leads to a determination of the projected surface area of the particles, this is related by a constant ($\frac{1}{4}$) to the total surface area of the particles, even if the particles deviate from a spherical shape by a considerable amount, provided that their distribution on the slide is reasonably random.

The calculated projected surface area and the photoelectric measurement for 52 such experiments are plotted in Fig. 2. Although there is some indication of a relationship, the scatter about the mean line is considerable. The average size of particle in each sample was then calculated, using as a measure of mean particle size, as is customary in such work, $\Sigma nd^2/\Sigma nd$, where n is the number of particles of diameter d in the sample.

It was found that points lying above the mean line resulted from experiments in which the average particle size was small, while points lying below the mean line were for coarse dusts. As an illustration, the average particle sizes are shown next to a few points in Fig. 2.

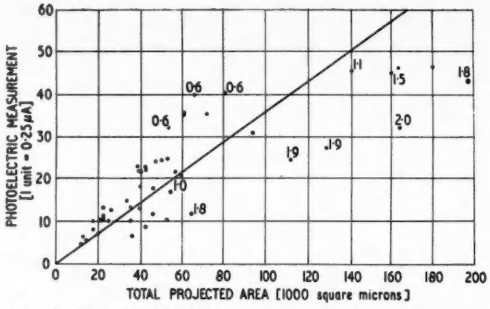

Fig. 2. **Relationship between photoelectric measurement and projected surface area.**

The ratio of the photoelectric reading to the projected surface area was then calculated for each experiment. The value of this ratio in each experiment is plotted against the average particle diameter in Fig. 3, giving what may be called the " response curve " of the apparatus. Deviations from the general trend are probably due mainly to errors in measuring the sizes and numbers of particles under the microscope, since the accuracy of this type of work is low. This response curve is of the shape indicated by theoretical calculations on this subject.

The results in Fig. 3 indicate that, for samples of coarse dust (average diameter greater than 1·8 microns), the photoelectric reading is directly proportional to the surface area. As the size decreases, the photoelectric reading per unit surface area increases and reaches a maximum of nearly three times the normal value when the average particle diameter is 0·5 to 0·6 micron in diameter. Below 0·5 micron, the extinction per unit surface area decreases sharply, as expected from the theory of light scattering.

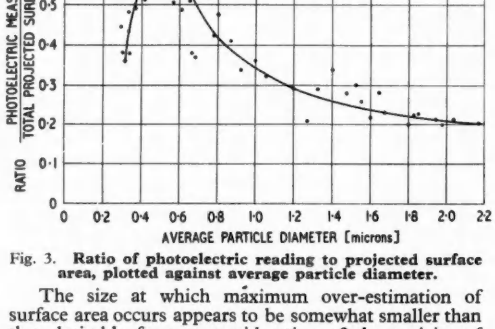

Fig. 3. **Ratio of photoelectric reading to projected surface area, plotted against average particle diameter.**

The size at which maximum over-estimation of surface area occurs appears to be somewhat smaller than that desirable from a consideration of the toxicity of silica dusts of different sizes. It might be suggested that the response curve should be moved to the right but, in the absence of precise quantitative data on the toxicity of particles of different sizes, it is not possible to specify how much the response curve should be shifted, nor to say if the over-estimation of the surface area by a factor of three at the peak of the curve is correct. All that can be said at this stage is that the response curve is apparently of the right order.

The position and shape of the response curve can be altered by using light of a different wavelength or photocells with a different wavelength response. In the absence of better pathological data, this step is not yet regarded as warranted, but to make it effective will not involve any major alterations to the present design of the apparatus.

From the response curve, the " extinction factor " for each particle size can be determined. This is defined as the amount of light extinguished per unit surface area of particle, relative to a value of one for large particles, i.e., particles where the extinction is directly proportional to the surface area of the particle.

Theoretically, the photoelectric apparatus should measure the total " extinction surface area " of all the particles in the sample, i.e., the sum of the projected surface area of each particle weighted by the appropriate extinction factor for that particle size. The total extinction surface area was therefore calculated for each sample in the experiments mentioned above, and was plotted against the photoelectric reading. Although there was some scatter about the mean line, the correlation is satisfactory and the relationship appears to be linear within the range of concentrations tested. This range covers the conditions normally found in Witwatersrand gold mines, if samples of 100 cc are taken on the modified thermal precipitator.

Similar experiments were made with dusts produced from a variety of other substances—coal, kaolin, sulphur, and various minerals, as well as dusts sampled in Witwatersrand gold mines (a mixture of quartz and various silicates). The weighting factors to obtain the extinction surface area of these samples were taken from the experiments on pure quartz. Graphs of the relationship between the photoelectric reading and the extinction surface area show that the mean line through the points agrees closely with that obtained for quartz, and, apart possibly from the results with sulphur, there is no evidence that any of the substances tested show a markedly different relationship to the others.

These results show that the measurement of the dust samples obtained in this apparatus provides basically a measure of surface area of the particles, with an over-estimate of the surface of particles between 0·5 and 2 microns, which are believed to have an enhanced toxicity per unit surface area, and with an under-estimate of the surface of particles below about 0·5 micron, which are believed to have a lower toxicity per unit surface area, and which probably play a minor role in the production of silicosis, owing to their comparatively rapid disappearance from the lungs by complete solution.

It must be stressed, however, that this is true only if this method of assessment is applied to a dust sample in which particles of various sizes are collected in the same proportion as they are retained in the human lung. If all particles in the air are collected in the sample, the surface area of the very large particles will usually completely outweigh the surface area of the smaller particles, but these larger particles will not reach the alveoli of the lung, and thus will play no part in the production of silicosis. The modified thermal precipitator was designed to sample selectively to reproduce, approximately, the human lung retention, and the combined use of this instrument and the photoelectric apparatus probably gives a more accurate assessment of the silicosis hazard of a dust than any measurement previously available.

The actual reading made on the instrument is electrical current, in microamperes, but this reading can be converted, by means of a graph, to extinction surface area, i.e., in square microns of surface per unit volume. However, it is suggested that, to simplify the use of the apparatus, the measurements be reported simply as a number, i.e., the reading on the galvanometer. This would follow local practice with the kata-thermometer, in which the unit of measurement is commonly ignored. Alternatively, some code word might be used as a unit. The important point is that the higher the reading on the galvanometer, the greater is the " dustiness " of the sample.

Materials Problems in Nuclear Power Reactors

By H. H. HAUSNER. (From *Materials & Methods*, Vol. 40, No. 1, July 1954, pp. 84-86, 1 illustration.)

In designing reactors, many of the problems commonly encountered in high-temperature service equipment must be met, together with additional complications, such as the effect of radiation on construction materials. This article indicates the operating conditions of some nuclear power reactors, at present in the design stage, mainly in connection with the types and temperatures of the fuel and coolants under consideration.

MOST current nuclear reactor problems concern materials. Probably the major role in the development of economically practical power reactors depends on their proper selection. There are still many unsolved problems in reactor engineering, and considerable research and development work is required in this field.

The gas-cooled reactor proposed by Commonwealth Edison in Chicago is designed for solid uranium fuel elements with an internal temperature between 1000 and 1300° F. Helium is proposed as the coolant gas, with an inlet temperature near 450° F and an outlet temperature in the range of 700 to 750° F, assuming a gas flow of approximately $3{\cdot}27 \times 10^6$ lb/hr. The total heat released will be of the order of 10^8 BTU/hr.

The reactor proposed by the Dow-Detroit Edison Co. is designed for a liquid-metal coolant such as sodium. The coolant temperature could be between 800 and 1100° F. A similar, but not identical, reactor has been proposed by the Monsanto Chemical group.

The thermal reactor designed by the Pacific Gas and Electric Co. uses water as a coolant (water temperature at inlet 380° F, at outlet 500° F; water pressure 1000 psig). The water temperatures are indicative of the temperatures which are to be expected in these nuclear power reactors.

All the reactor elements, the fuel, coolant, coolant transportation system, the moderator, any internal structural materials, and the reactor control elements, will necessarily operate at elevated temperatures. The materials problems in the design of reactors are, therefore, characterised by the behaviour of metals and the reaction between metals at elevated temperatures and under irradiation. These problems include :—(a) Mechanical behaviour at elevated temperatures, especially strengths, such as tensile strengths, creep, impact, and fatigue strengths; (b) corrosion behaviour; (c) heat transfer and thermal conduction; (d) thermal shock behaviour of metal and non-metal combinations; (e) radiation damage.

Some of these problems are of a physical, chemical, or metallurgical nature. There is no precise borderline between physical, chemical, and metallurgical problems, and it can be said, in general, that they concern solid-state phenomena. There are, of course, other materials problems connected with neutron absorption cross-sections of the reactor materials and the formation of radioactive isotopes in the removable components, while a problem of prime importance concerns the recovery of the unused fuel after removal from the reactor. It may be stated that many of these problems cannot be solved by classical methods, and consequently new methods must be developed.

METALLURGICAL-MECHANICAL PROBLEMS

These problems concern practically all the metals in the reactor, those for structural purposes, as well as those which may be called operating parts, including the fuel metal, the fuel cladding, the coolant, the moderator, and the shielding.

The basic difference between the fuel metal and other common metal parts at elevated temperatures can best be described by the difference in the direction of heat flow. Common metals during heating usually receive the heat from the outside, whereas the fuel metals produce the heat internally from fission. While common metals can be heated from the outside to a uniform temperature throughout, the fuel metal producing heat under irradiation will always have a higher temperature gradient between the centre of the fuel element and the surface. This gradient is a function of many variables, the most important of which are (a) neutron flux, (b) shape and physical dimensions of the element, (c) type and circulating speed of the coolant, and (d) thermal conductivity of the fuel material.

Any mechanical calculations concerning fuel elements must take both this temperature gradient and the resulting stresses into consideration. These stresses, however, make predictions of the behaviour of the elements very difficult. They affect the strength and creep properties, as well as the stress-to-rupture values and the fatigue of the material.

In addition, these stresses are of prime importance in all problems concerning the bond between a solid-fuel metal and the protective fuel-element cladding. Any high-temperature reactor utilising solid metallic fuel elements needs a reliable bond between fuel metals and cladding, especially for reasons of heat conduction. The cladding metal must be chosen very carefully. It requires a low neutron absorption cross-section for neutron economy, its thermal expansion must approach that of the fuel metal, and it must resist corrosion under operating conditions. As the fuel elements operate at elevated temperatures, care is required to avoid diffusion of the fuel metal into and through the cladding during operation.

Difficult metallurgical-mechanical problems are encountered with the coolant and coolant transportation system, when the coolant is a liquid. Liquid metals are highly desirable from the point of view of heat conductivity and, as long as the temperature conditions are stable, the mechanical problems concerning the liquid-metal coolant are relatively simple. However, in cases of non-uniform temperature conditions, there is a danger that the liquid-metal coolant may change its viscosity and, as a result, the friction conditions between coolant and the coolant transportation system. Non-uniform temperature conditions may therefore effect the circulation speed of the coolant and thus the heat transport itself. Mechanical problems in connection with coolant circulation pumps and the purification system will be immense if coolant viscosity changes.

Attention must also be given to the reactions of the liquid-metal coolant with structural reactor materials. Several types of attacks in liquid metals are possible, especially the direct solution of a material or its constituent, intergranular penetration, formation of intermetallic compounds, and others.

Another mechanical problem with respect to the coolant transportation system is leak tightness. The tightness of the coolant pipe lines, circulation pumps, heat exchanger, etc., is of greater importance in nuclear power stations than in conventional power stations. In the nuclear power station, the radioactive coolant, by penetrating any leaks in the system, would cause damage and dangers (fire, radioactivity) hardly to be evaluated in advance and practically impossible to correct after the damage was done. If this happened, a complete enclosure for the reactor would be necessary. Of course, structural materials used in the reactor must be carefully chosen, to withstand the temperatures and radiation encountered, while at the same time avoiding undue neutron losses.

Corrosion

Most of the corrosion problems in a nuclear power reactor are connected with the type, temperature, and pressure of the liquid coolant. There is general agreement among reactor designers that the fuel material should be placed in a sealed container, in order to prevent corrosion and erosion by the coolant. However, even in cases where the nature of the coolant does not promote corrosion, as in the use of gaseous coolants such as argon, it will be necessary to clad the fuel material, in order to prevent radioactive fission fragments from entering the coolant.

Some of the metals to be considered for cladding materials or for coolant pipe lines have been developed only recently and little is known about their corrosion behaviour. Where liquid metals are used as coolants, there is a certain danger that they may react with the cladding material. Corrosion in a nuclear power reactor may take place at the following points :—(a) Between fuel cladding and coolant ; (b) between fuel metal and coolant, in the case of imperfect cladding ; (c) between coolant and coolant transportation systems, including the welded joints ; and (d) between coolant and heat exchanger or heat engine.

Static corrosion tests are not sufficient for testing the materials under consideration, since the coolant in the reactor circulates under pressure at a fairly high speed. Corrosion problems are extremely difficult where welded joints must be used, since rates of corrosion may be increased by the presence of alloys formed during welding.

Many investigations of the corrosion resistance of various metals and alloys in liquid sodium were made under static and dynamic conditions. Pure iron, ferritic stainless steel (12·27% Cr), and austenitic stainless steel (18-8 and 25-20 Cr-Ni) have shown excellent corrosion resistance up to high temperatures, whereas low-chromium steels and mild carbon steels show only poor corrosion resistance at temperatures above 100° F. Zirconium does not corrode up to 1100° F in liquid sodium, but shows only limited resistance at 1470° F.

Temperature differentials in the flowing liquid metals result in interesting phenomena. Since solubility of a material in liquid metal depends on temperature, increased attack is possible by the so-called mass-transfer process. Some metals dissolve in the hottest part of the coolant system until the coolant is saturated at that temperature. This metal then precipitates in the cooler zones until saturation at the low temperature is reached. Mass transfer is a metallurgical problem which requires further careful investigation.

Recent research and development work is directed towards the application of ceramic materials for power-reactor purposes. Among the ceramic materials for fuel elements with high melting points are uranium oxide (5072° F), uranium carbide (4892° F), and uranium silicide (3092° F). Ceramic materals with high neutron-absorbing power include hafnium oxide and boron carbide. Corrosion tests have shown that ceramic materials offer many advantages in nuclear power reactors. However, their low resistance to temperature shocks makes application of these materials difficult.

Heat Transfer and Thermal Conduction

The useful thermal output of a nuclear power reactor depends on the operating temperature and on the efficiency of heat transfer from the fuel element, where heat is generated, to the heat engine, where heat is transformed into mechanical and electrical power. In order to obtain good heat transfer, the problem of thermal conduction must be carefully evaluated in the design of reactors. Thermal conduction between fuel metal and cladding and between fuel cladding and coolant, as well as between coolant and heat engine or heat exchanger, has to be studied especially carefully.

Any variation in thermal conduction between fuel metal and cladding material can be detrimental to reactor operation. The bond between fuel core and cladding must be satisfactory and reliable from a number of standpoints. Any non-uniformity in the bond can cause overheating in certain spots and in this way may cause stress, grain growth, and dimensional distortion. Hot spots also promote diffusion of the fuel metal into and even through the cladding material. In the latter case the coolant and eventually the whole system will be poisoned. The bond between fuel core and cladding therefore must not only be uniform but must also prevent diffusion of the fuel metal through the cladding material. The bond must further be proof against temperature shock, as a protection against failure if the reactor is suddenly shut down. The production of a satisfactory bond between fuel metal and cladding, although appearing to be a simple problem, actually represents a major one.

Another thermal conduction problem arises at the interface between the fuel cladding and the coolant. Poor wetting properties of the coolant or poor thermal conduction of coolant can hinder heat removal. As the materials for construction in a reactor frequently must be made from "uncommon" materials, this heat-conductivity study represents entirely new problems in many cases. The cooling of the moderator system represents another difficult problem of heat conduction.

Radiation Damage

Radiation damage is an important problem in reactor design and is a problem entirely different in nature from any other. Experience in this field is new and experimental results are still incomplete. Metallurgists and solid-state physicists are still searching for a correct theoretical explanation of the phenomena observed.

During the last few years, it has been shown that the physical properties of many materials change under radiations. These changes vary with the type, density, and duration of radiation, and also with the type and structure of the material. It is fairly well agreed at present that organic compounds are affected by beta, gamma, and neutron radiation, and the disturbances in the material can be well explained by ionisation. Metals, however, being good electrical conductors, seem to be affected chiefly by neutrons. Some of the experimentally observed disturbances in metals can be explained and correlated on the basis of a lattice-vacancy picture, which considers displacements of atoms from their normal crystal lattice positions. It is understandable that the kinetic energy of a fast neutron is high enough to displace atoms during an elastic collision and thus to disrupt the material. By such collisions, the creation of a number of lattice vacancies may be expected, and the removed atoms may also displace still other atoms from the lattice. It is also possible that these displaced atoms excite lattice vibrations of a mean energy corresponding to a temperature higher than the average temperature of the material.

One of the most important results of radiation is dimensional change, often called "radiation damage". It is interesting to note that most of the changes in the physical properties of metals on exposure to neutron radiation have a certain resemblance to the changes occurring as a result of cold working, although the mechanism of these two types of changes are of an entirely different nature. It also appears that a correlation exists between the degree of cold working, the heat treatment of a metal, and the extent of changes under neutron radiation.

The disturbances in metals caused by radiation represent one of the greatest materials problems in the design of power reactors, and development work in this field may eventually lead to entirely new types of materials.

Methods of Producing Wire by Powder Metallurgy

By H. FRANSSEN. (From *Draht* (English Edition), No. 25, August 1954, pp. 42-44.)

METHODS of producing wire by powder metallurgy can be divided into the following four groups :—

(1) Those processes which have to be carried out by powder-metallurgy methods because the melting points of the metals are too high to permit their control in the liquid state.

(2) Those processes in which billets can be produced by extrusion. These billets are subsequently drawn into wire.

(3) Attempts to produce wire or semi-finished wire by direct rolling or by continuous pressing of powders.

(4) Processes in which strip produced by powder metallurgy is split into separate oblong or square stock, which is subsequently drawn.

(1) SEMI-FINISHED WIRE BY HAMMERING

Metals which can be worked only by powder-metallurgy processes chiefly comprise those required for incandescent lamps, i.e., tantalum, osmium, tungsten, and also possibly thorium. The individual steps in the process are, briefly, the following :—Tungsten, tantalum, or thorium powder of a certain selected grain size is pressed in steel dies in hydraulic presses at a minimum pressure of about 6 tsi. The addition of highly volatile bonding agents to the powder, such as camphor dissolved in ether, paraffin wax in benzine, and glycerine, raises the mechanical strength of the pressed component sufficiently to permit further treatment, which consists mainly of sintering. This treatment is intended to increase the strength of the pressed component to such a degree that it can safely be subjected to the actual manufacturing process.

The sintering process comprises two stages, namely, pre-sintering and final sintering ; the former serves to prepare the component for the final sintering operation and consists of annealing the still very porous rod in a reducing atmosphere at about 1830 to 2010° F, in furnaces with molybdenum heating elements. After the pressed component has been treated by pre-sintering, it can be subjected to the final sintering operation, in which it is heated by the passage of an electric current to maximum temperatures of about 5070 to 5790° F.

Further processing consists of drawing the wire in diamond or cemented carbide drawing dies ; generally, only diamond dies are used for wire which is less than 0·02 in. in diameter. In order to obtain the most ductile wire, continuous hammering is stopped when the diameter of the wire has been reduced to 0·12 to 0·16 in. The wire is then drawn from this size. The wire is heated after each pass and the temperature progressively lowered as the diameter decreases. Fine wire is drawn cold. The graphite layer is removed from the finished product in various ways, e.g., by boiling with caustic soda, but no entirely satisfactory method has yet been found. Electrolytic pickling can be successfully applied to wire of relatively heavy gauge.

(2A) BILLETS BY EXTRUSION

Metals which, owing to their high melting point, are processed into wire by the method described above, can also be extruded as billets for further processing into wire. Special plasticisers must, however, be added to the powder, as the extrusion of wire from powders presupposes sufficiently favourable welding and flow properties to render the powder, in effect, hydrostatic in the hopper of the extrusion press. Powders with poor flow properties tend to build up pressure on the containing surfaces, so that a part of the applied pressure is dissipated as friction. It is therefore not surprising that hard materials, such as pure tungsten carbide, cannot be extruded. The process becomes possible, however, as soon as plasticisers such as polystyrenes[1] are added. It is evident from recent patent applications that the same result can be achieved by liquefying, at a sufficiently high temperature, the bonding agents present in the cemented carbides, i.e., cobalt or other metals of the iron group, which then act as lubricants.

The paste method can be regarded only as a preliminary stage to extrusion in the powder-metallurgy production of wire or other components, though it is of historical interest. Recently, this relatively old process has again acquired some importance, as it enables very fine cemented carbide powders to be extruded successfully.

The colloidal method developed by Kuzel[2] and the method of Orbig and Schaller[3], both of which have also acquired a certain industrial significance, can be regarded as variations of the paste method.

Kuzel bases his process on the fact that tungsten, atomised by a submerged arc, forms a material sufficiently plastic for injection, as, apart from the oxides, it contains the metal in colloidal form. The oxides are reduced in the subsequent sintering process.

Wires, often up to several yards in length, can be produced from single crystals by the Orbig and Schaller method. In this process, extremely fine tungsten powder, the grain size of which should not exceed 0·5μ, is mixed with 2% thorium oxide and extruded by the paste method. During sintering, the wire runs through a thick-walled tungsten coil, which is heated to just below its melting point in a reducing atmosphere. Owing to the inhibiting action of the foreign oxides on grain growth, the grain size of the wire, which passes through the spiral continuously and preferably in long pieces, is increased only in the hottest zone at about 3630 to 3990° F. In this range, the small crystals are incorporated into the large crystals. The length of the individual crystals depends, however, on striking a successful balance between the speed of the wire in passing through the spiral and the rate of increase in grain size. The size of the crystals obtained varies inversely with the speed of the wire.

(2B) DIRECT EXTRUSION

The patents of Esser[4] and Krall[5] describe the first important methods for actual extrusion, i.e., the forcing of metal powders through nozzles or dies, under the simultaneous application of heat. Esser suggests cold pressing of spongy iron powder into components having a density of 60 to 90% of the theoretical maximum, which can then be further formed in hydraulic extrusion presses at temperatures of approximately 1290 to 2370° F. This process can be applied to almost all ductile heavy metals, such as gold and silver, and also, at suitably lower temperatures, to components pressed, for example, from lead or aluminium powder. In his patent specification Krall outlines a method for extruding alloys based on tungsten-copper or tungsten-silver compositions into wires and sections. In this process, a powder mixture consisting of at least two components of different melting points is consolidated by pressing at a temperature below the lower melting point. The density of the pressed component is then increased mechanically under very high pressure at a temperature below the lower melting point.

The process is characterised by the high proportion, amounting to at least 80%, of metals with high melting points (W, Mo, Ta) in the mixture of powders. The remainder must consist of at least one of the metals Cu, Ag, and Au, of lower melting point. Pressed components of such compositions are then extruded under

a pressure at least twice as great as that applied in the first pressing stage, and at a temperature amounting to 70 to 90% of the lowest melting temperature.

It is surprising that even aluminium powder, the surface of which is covered by a film of oxide, can be extruded (for instance, by the SAP method)[6]. The importance of this process lies in the fact that aluminium powder can be used for the production of tubes and other forms of material, such as wire, which retain their good mechanical properties even at elevated temperatures, in contrast with the materials previously obtained by cold working and heat treatment. The raw material used in this process is an aluminium powder, such as commercially available flaky aluminium powder; the size of at least 50% of the particles must not be greater than 2μ. At the very high extrusion pressure used, the ductile, pure aluminium ruptures the films of oxide, which are occluded as phenocrysts in the cold-welded aluminium rod. Other elements, also in powder form, can be added to the aluminium powder, either as such or in chemical combination; key alloys containing aluminium can also be added. The powders are initially pressed to billets, which are then sintered at elevated temperatures and subsequently formed, mainly by extrusion. Satisfactory results are also obtained in the extrusion of surface-oxidised aluminium powders without preliminary sintering.

Products with a tensile strength of more than 15 tsi are obtained by cold pressing and hot forming (without special sintering or heat-treatment) at temperatures of about 570 to 930° F.

12·7 tsi is suggested as the most suitable pressure for the preliminary cold pressing, while the pressures applied in hot pressing are limited only by the maximum permissible load on the press tools. A temperature of approximately 1020 to 1110° F is considered to be particularly suitable for hot pressing and sintering; at any rate, the temperature should be above 750° F.

Hardness varies directly, while tensile strength and elastic limit vary inversely, with the amount of oxide present. It is to be expected that this method of manufacturing wire will be put into practice in the near future, particularly as the data supplied by the patentees indicate that the conductivity of the wire is not significantly affected by the occluded oxides.

Kaschke and Vogt[7] describe a process which can also be considered to be a form of extrusion, by means of which bar stock for wire drawing can be obtained. Metal powder is consolidated in a tube by the regular reciprocating movement of a plunger, until a certain degree of compression has been reached. The rod thus formed either moves forward to the outlet or is further compressed by passing through a special die. The author, however, is not aware of any practical applications of this process.

(3) Rolling Powder into Wire

Direct rolling of metal powder into wire, which subsequently merely needs to be compressed and drawn to the required gauge, must be considered the ideal solution. Rolling powders into round sections presents certain difficulties which, in the case of hot-rolling, are of secondary importance, owing to the excellent flow properties of the heated material. The rolling speed at the base of the profile for the wire differs considerably from the speed near the surface of the roll; this phenomenon has a most undesirable effect, especially in the rolling of powder. Moreover, the ratio of the width across the profile to the width of the sizing gap varies according to the method of measurement. Attempts have therefore been made to roll wire by using three to six rolls which, together, determine the gauge of the wire[8]. It is suggested that the rolling mill be constructed in such a way that at least three rolls should form a closed sizing gap and, at the same time, rotate round axes which are not parallel, but which intersect in at least two finite points. This type of rolling mill is suitable for the formation of bar or wire from hot liquid metals, certain plastic materials, powders which can be pressed, and rapidly setting pastes and mixtures. Owing to the highly complicated mechanical requirements of the system, this method is expensive and it may therefore be assumed that it is unlikely to be used in practice.

(4) Subsequent Drawing of Strip Produced from Metal Powders

The manufacture of types of wire which are used in large quantities, mainly copper, iron, or bronze wire, by the methods described above, is economically unpromising. Methods are required by which large quantities can be produced simply. This criterion is not met either by the sintering of blocks with subsequent working, by extruding, or by rolling to the size required. On the other hand, the subsequent drawing of strip produced by powder metallurgy may become important. This method has been known theoretically for a long time, but could not be applied practically in the past, because of the difficulty of separating the large number of wires in one endless band.

To-day, it is theoretically possible to manufacture bands of any desired length by powder metallurgical methods. For this purpose, the required metal powder is fed into a rolling mill, in which the rolls are arranged adjacently and horizontally, and in which the powder is consolidated into a strip by the rolling pressure.

This arrangement was first described by Siemens[9]. The advantages of the rolling method over extrusion are that it is possible to feed the powder uniformly into the rolls, and relatively high specific values can be obtained for the pressure, which, at any given moment, acts only on very small areas. The metal, which has been fed into the mill in powder form, leaves the rolls as a continuous strip or as filaments. After repeated sintering carried out by a continuous method, a sufficiently wide, endless band of this kind has adequate mechanical strength to enable it to be cut without difficulty into narrow strips of oblong or square cross-section, which can then be drawn to ordinary wire in a few passes.

The fact that the production of copper wire from copper powder has not been carried out by this method in the past is explained by the economic advantages of the conventional production process which starts with ordinary rod or bar as the raw material. It is, however, quite possible that changes may occur in the near future, as the American Cyanamide Corporation has, in the meantime, developed a chemical method of producing cheap copper powders. In this process a powder of extremely uniform grain size and of a high degree of purity is directly obtained chemically by reducing complex salts of copper with carbon monoxide or hydrogen at elevated pressure and temperature. The cost of the powder is competitive with that of electrolytic copper, so that the method of producing wire or a semi-finished product by powder metallurgy becomes, in general, far cheaper than the previous method of hot-rolling ingots or wire bar. This development is particularly important, because the process for manufacturing semi-finished strip from these copper powders is already available and is, in fact, practised in pilot

(*Concluded on page* 437)

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Experience with Hydrogen Peroxide for the Production of Power

By HELLMUTH WALTER. (From *Jet Propulsion*, Vol. 24, No. 3, May-June, 1954, pp. 166-169, 3 illustrations.)

Hydrogen peroxide as a source of power is widely known and many details of its application have been published. There seems to be, however, some doubt about the safety of its application. This report is intended to fill this gap, by describing accidents and special experiences with H_2O_2 against the background of its multiple applications in Germany in a 10-year period before and during World War II.

IN April 1933, while searching for a means of driving a submerged submarine at much higher speeds than the conventional 6 or 8 knots, the author proposed the use of hydrogen peroxide for this purpose, and asked the Electro-Chemical Works, of Munich, the usual questions regarding stability, explosivity, concentration, etc. The answer, on the whole, was encouraging, except that only 60% strength hydrogen peroxide could be offered at the beginning. Decomposition tests at atmospheric pressure were soon initiated. The results showed increasing promise, as the strength of the solution and the decomposition pressure were gradually increased.

Soon, the German Naval Command became interested, but first insisted on making detonation tests before hydrogen peroxide was used in engines. A small quantity of 80% hydrogen peroxide was put into a strong solid-lead cylinder and was exploded with a strong detonator ($Pb(N_3)_2$). No appreciable enlargement of the hole was measured, as compared with applying the same detonator to water. Consequently, it was considered that hydrogen peroxide, up to 80 to 82% strength, could not be detonated.

In a second series of tests, 80% hydrogen peroxide was decomposed in an extremely strong vessel made from 18-8 steel, by injection of various quantities of a permanganate solution, to determine the effect of high pressure on the decomposition. There was a strong indication that high pressure did not accelerate decomposition, but that it was actually retarded. This effect, as well as non-detonability, was considered to be an important basic property of hydrogen peroxide, if it were to be used for the Armed Forces. At about the same time, the first somewhat crude decomposition tests with 80% hydrogen peroxide solution were made at pressures up to about 450 lb, with a throughput of approximately 5 lb/sec.

In 1935, a very serious accident occurred to several physicists in the service of the German Army Command, who tried to develop an H_2O_2 monofuel. They used a solution of hydrogen peroxide (80%) and alcohol in stoichiometric mixture. The solution seemed to be stable, and 100 lb of it had been carried in a glass flask over 400 miles in an automobile to its destination. A test apparatus had been built, consisting of a pressure vessel, pipes, check valves, and a combustion chamber, made of 18-8 stainless steel. The whole apparatus, including the pressure vessel, detonated soon after ignition. Armoured plates were pierced by fragments and three persons were killed.

Research tests with hydrogen peroxide-alcohol solutions were subsequently made, and the limits of detonability were established. However, we never used any hydrogen peroxide-fuel solutions for any of our rockets or engines, though we did make decomposition tests with "non-detonable" solutions, using a solid-surface catalyst, and found the expected increase in temperature from approximately 450° C for an 80% hydrogen peroxide solution to approximately 700° C for the hydrogen peroxide/water/alcohol solution. The accident mentioned above did not, however, retard work. On the contrary, during the period from 1936 to the outbreak of World War II in 1939, hydrogen peroxide was firmly established as a source of power for military purposes in cases where air was not available or where great power or thrust had to be produced for a short period of time. No further accidents occurred during this period.

The major achievements may be listed as follows :—

By the end of 1936, about 1000-kg thrust had been developed. Shortly after, 4000 bhp was measured on a gas-turbine plant which had previously been developed and converted into a hydrogen peroxide power plant. In each case, a permanganate was used as a catalyst with some alkali, either in solution with water or in paste form. Soon, a great number of applications branched out from these tests.

EARLY FLIGHT TESTS

The first flight with a liquid propellant took place in February 1937, with 100-kg thrust. Later in that year and during 1938, numerous flight tests were made with assisted take-off units at 300 to 500-kg thrust, with land- and sea-planes, without any accidents whatsoever. All of these were monofuel devices working with 80% hydrogen peroxide. Several unguided missiles were tested, among them a midget prototype of the V-2, which climbed to a height of 18 km and broke through the sound barrier. Rocket-propelled depth charges were thrown over a distance of 200 metres, and sea mines, dropped from an aircraft, were decelerated so that they fell gently into the sea. During the summer of 1939, the first aircraft (Heinkel 178) took off, propelled solely by a controllable rocket. The first torpedoes were launched just at the outbreak of the war. In this case, the propulsion engine was used with a dual-fuel system, i.e., kerosene and hydrogen peroxide. A single-cylinder, 30-hp diesel engine was run for 1000 hr on decomposed hydrogen peroxide vapour as a monofuel. Later, a 300-hp submarine diesel engine was tested in the same way. The accumulation of oxygen in the crankcase had to be watched, and could be avoided by blowing cooled fuel exhaust gases through it.

Though no major or fatal accidents can be reported during this period, there were, of course, a number of technical failures. None, however, occurred during a flight. During shop tests, a number of accidental explosions, some of minor importance, occurred.

There was, for example, the hydrogen peroxide pump used for the 4000-hp marine power plant. The entire pump had been made from 18-8 stainless steel. It happened that the stuffing box, packed and greased in the conventional way, blew out several times. On each occasion, it had been too tight and became too hot. Small quantities of hydrogen peroxide had reacted with the hydrocarbons of the grease. The casing had not been destroyed, but the screws were broken. Later, a grease of paraffin and talcum was developed, and this gave no trouble when it was applied. In addition, dynamic seals and Buna-rubber sealing rings were developed.

H_2O_2 PRESSURE-VESSEL TESTS

Tests were made to ignite hydrogen peroxide and kerosene in a torpedo combustion chamber. This caused, on one occasion, a fairly heavy explosion in the test cell, so that the previously developed catalytic ignition, which had never given any trouble before or after, was retained. This catalytic ignition was later improved by using self-igniting fuel (hydrazine hydrate) plus alcohol in solution.

An aluminium pressure vessel (1500 psi) exploded one night. It had been left filled (approximately 5 gal) overnight because, for some reason, the test could not be made the previous day. Afterward it was found that

the aluminium alloy contained copper. Similar events occasionally occurred later, if small quantities of hydrogen peroxide were left in the container after a test. Sometimes, the hydrogen peroxide decomposed without any explosion; sometimes, it was possible to cool the vessel with a jet of water.

Tests were made to heat a pressure vessel filled with hydrogen peroxide over an open fire. The vessel exploded as soon as the vapour pressure was high enough, in the same way as a water- and steam-filled vessel exploded. No additional effect was noted. This test was made because a 10-ton truck, loaded with H_2O_2-filled aluminium containers, had run into a tree, and caught fire. The fire was soon under control and no explosion occurred. Over a 10-year period, thousands of tons of hydrogen peroxide were transported, at first by trucks and later by rail in special cars, without accidents, except for the above incident.

Storage Facilities and Mass Production

Storage facilities were still in the development stage during this period. The material of the tanks was, in most cases, pure aluminium. Coating the inside of the containers with paraffin and hard polyvinyl chloride, for instance, was tried, but unprotected aluminium proved to be satisfactory, if kept clean. At the same time, the stabilisers were improved, and finally a purer product was made by dual distillation. In the few instances recalled, when a large storage tank started to show an elevated temperature, which is invariably connected with decomposition and which occurs very slowly in large tanks, the process was brought to a halt temporarily by acid additions. If the quantity of H_2O_2 was large enough, it was sent back to the producer and redistilled. In most cases, however, it was mixed with a higher per cent hydrogen peroxide and immediately used for tests.

The last period, during the war years, saw not only a still further increase in development work but also the beginning of mass production of hardware by various firms other than that of the author. By the end of the war, the number of plants had increased from one to five and the number of employees from approximately 500 to over 4000. Two of the plants were assigned to development work and the three smaller ones to the production of prototypes. Also, three permanent test bases had to be built, manned, and equipped—one for submarines, one for torpedoes, and one for launching ramps. Groups of field service engineers were located at half a dozen other places, and hydrogen peroxide was to be found everywhere. If the safety of its application had been seriously questioned at any time, it would not have been so widely used. However, the war years did not pass entirely without accidents, as will be described later.

Development of Assisted Take-off Units

In general, dual-fuel (combustion) propulsion units came more and more into the foreground and with them self-igniting fuel. However, during the first one or two years, there were some exceptions. The 500-kg monofuel assisted take-off unit (ATO) was in mass production when the war began. The Heinkel III and Junkers 88 bombers were equipped with ATO units. Many thousands of the rockets were produced and tested, using only air and water to simulate the proportioning of the H_2O_2 and permanganate solutions. It was perfectly safe to make the first actual thrust run with hydrogen peroxide during an actual take-off. The ATO's were then parachuted and re-used up to 60 times. Altogether, there had been thousands of take-offs from about twelve different air bases in Europe and later in Russia. Towards the end of the war, they were used less and less and, finally, only for special purposes as, for example, for reconnaissance. In 1940, there were two or three reports of failures. In every case, one of the two devices failed to work and the planes crashed. In each case, the cause was found in the failure of the electric switching device. At no time was the use of hydrogen peroxide for ATO's considered to be dangerous. The only other accident which occurred, to the author's knowledge, happened shortly before the war, when a Heinkel airplane took off in an attempt to break the world long-distance record. It was equipped with four 500-kg ATO's. During take-off, the undercarriage broke down. The two ATO devices in use took off after the crash, while the two other remained filled and ready under the wing. There was no fire or explosion and the crew was unhurt. This accident shows that hydrogen peroxide does not add to the hazards of flying.

Just before the self-igniting fuel was ready for application, we developed and built prototypes of a 1000/1500-kg ATO, which worked on hydrogen peroxide, liquid catalyst, and gasoline, i.e., with full combustion plus decomposition. The unit, in contrast with the previously described ATO's, could be shut down at any time, The fuel was ignited and combustion maintained by a constant flow of a liquid catalyst. This device was used on many occasions for flight tests, but never in the field. For instance, a guided missile was propelled by it, and four of them helped to get the newly developed Ju-287 jet-engined bomber off the ground. Four 1000-kg ATO's were used for additional thrust. After the war, some of these devices were taken to England, where one of them was tested and caused a fatal explosion in which three men were killed. As usual, in most fatal accidents, several unfavourable factors worked together to cause the death of several people. It must, however, be admitted that this type of rocket, with three different fluids which had to be controlled with the right sequence, was more complicated, less reliable, and required more skilled personnel than the rockets developed previously and later. This device also was electrically started and controlled. About 1000 actual laboratory and flight tests were made safely before this accident occurred.

Launching Ramps and Torpedoes

The development and application of the fully controllable "cold" and "hot" rocket engines for the Messerschmitt 163 A and B, with up to 5000-lb thrusts, never, as far as the author is aware, caused any serious accidents. Mechanical troubles were surprisingly rare for such a new and powerful engine. There were, altogether, several thousand flights.

During the development and during numerous field applications of the launching ramps, no accidents occurred, except for those mentioned above with the switch. Several engineers were assigned permanently to the staff of the V-1 regiment. The men usually stood unprotected close to the ramp, when in operation, as in firing a gun. About 200 lb of H_2O_2 were decomposed in one second.

In connection with the torpedo development, two accidents can be reported. One not very heavy explosion occurred while the torpedo was still inside the tube. Several men were injured, though not fatally. The cause was easily corrected and never developed again. However, a second explosion, which caused the death of three men, occurred inside a torpedo which had been salvaged after it had been lying on the sea bottom for at least one month. As soon as the men started to dismantle it, an explosion took place, caused probably by a mixture of kerosene and hydrogen peroxide. The development of a torpedo engine was a most difficult task because of restricted space, high performance requirements, switching the unit off and on, and the storage of relatively small quantities of reactants over a long period of time at elevated temperatures. By far the best results were obtained with a bi-propellant torpedo, using approximately 50% hy-

drogen peroxide and 50% hydrazine hydrate solution. This torpedo, however, was developed for aircraft only. The number of failures during the torpedo development was considerably greater than in other applications. The author believes that the cycle should be simplified and the mechanical requirements reduced. Even so, it may be difficult to make the hydrogen peroxide propulsion system a success in this field.

Submarine Engines

The situation during the 10-year period of the development of submarine engines was entirely different. In this engine, the 80% H_2O_2 was first decomposed into harmless steam and oxygen gas, which was then combined with fuel oil in a burner. Until a reliable solid catalyst was developed, the start of the decomposition had to be watched and any accumulation of liquid avoided. On one occasion, such an accumulation, followed by a sudden decomposition, caused the handhole of the decomposition chamber to be blown out.

On another occasion, a fire was started by a leaking hydrogen peroxide bag, owing to the fact that the steel compartments were, by mistake, painted with a mercury paint. This occurred while the submarine was in dry dock and while there was no sea water around this bag. The reaction was rather violent. The hydrogen peroxide started to burn the bag, but the fire was quickly extinguished by flooding the dock. The first test submarine of approximately 80 tons displacement was equipped with a 2500-hp turbine working on H_2O_2 vapour only. After the submarine was considered fit for sea trials, a speed of 26½ knots was achieved, submerged. No serious troubles were encountered during the lifetime of this submarine, although a great number of changes and improvements, especially in the storage and piping system for hydrogen peroxide, had to be made. The catalyst during that period (1940 and 1941) was still unsatisfactory. On several occasions, a fire started after the turbine had warmed up, caused by vapour leaking through the glands of the turbine and igniting the lubricating oil of the bearings. Great pains were taken to avoid any hydrogen peroxide leaking into the operators' compartment. In spite of this, it happened that a small quantity of hydrogen peroxide leaked into this compartment and started to decompose slowly in the bilge. The atmosphere resulting from the decomposing hydrogen peroxide became unbearable for the crew. The submarine had to be surfaced quickly and was nearly lost as a result of further mistakes being made. The piping of the leaking gauge was changed and no further mishaps occurred. During 1941 alone, 80 sea trials were made with at least 1000 tons of hydrogen peroxide being used, and it was generally acknowledged that hydrogen peroxide could be used in ships and that it was possible to handle and control the submarine at speeds up to 26½ knots, submerged.

For full-scale tests and for training purposes, 300-ton submarines were built and completed in November and December 1943, and handed over to the German Navy in December 1944. These submarines carried approximately 45 tons of hydrogen peroxide and developed 4500 hp, using two turbines on one shaft. During 1944, about 200 sea trials were made and several thousand tons of hydrogen peroxide were used. During 1945, several more submarines of this type were completed, and the war ended just when some of them had completed their tests. Nothing can be reported which would in any way have cast doubt on the usefulness of hydrogen peroxide for submarines and, consequently, the submarine building programme of the German Navy included predominantly a great number of hydrogen peroxide-driven boats of 7500 shp.

Other tests which might be of some interest were carried out with incendiary bombs, explosive bombs, and 500 kg of hexogen (a powerful new explosive) upon both small and large storage tanks filled with 82% hydrogen peroxide (maximum, 5 tons of H_2O_2). With the incendiary bombs, which included one phosphorus-gasoline bomb, no great effect was found on the stored hydrogen peroxide. Decomposition, if any, came to a standstill after a short time.

A 200-lb bomb, exploded in the centre of a 5-ton storage tank, gave no additional effect, as compared with an explosion in a water-filled tank. However, it was the general belief that, in the case of using 500 kg of hexogen, there was some additional effect, caused by thermal decomposition of hydrogen peroxide. It might be added here that numerous tests were made with torpedo hulls, in which hydrogen peroxide, kerosene, igniter fuel, and feedwater had been stored in various arrangements. Rifle shots and explosive ammunition were fired at these hulls. The safest arrangement was one in which the diluent water surrounded the H_2O_2 and the kerosene.

Conclusions

It may be of interest to make the following statement :—" Of all devices finally accepted and introduced into the German Armed Forces, there was no case where any accident was attributed to the use of hydrogen peroxide or where hydrogen peroxide might have aggravated and otherwise caused accidents."

The following devices had been accepted and were in use either for training or in the field and handled by the troops alone :—

(1) 500-kg ATO H_2O_2 monofuel units. Several thousand of these units were built.

(2) At least 1000 300-kg thrust, rocket propulsion units for guided missiles were built.

(3) Bi-propellant 1000- to 1500-kg ATO's. Several hundred units were built, but used for tests only.

(4) Catapults with hydrogen-peroxide propulsion units (decomposition only) for launching the V-1's. Several hundred of these units were built and were used thousands of times.

(5) Controllable propulsion of a 750-kg thrust unit for the Messerschmitt 263.

(6) Rocket training aircraft and the controllable power plant of up to 2000-kg thrust for the Messerschmitt 263 B. Several hundred of these units were built and used thousands of times in the field.

(7) Altogether, up to the end of World War II, seven submarines of 300 to 330 tons were accepted by the German Navy. These were considered to be developed beyond the test stage.

It can be safely assumed that hydrogen peroxide has been applied more than 10,000 times by the services, during which time no accidents were reported to have been caused by the application of this propellant.

METHODS OF PRODUCING WIRE BY POWDER METALLURGY

(*Concluded from page* 434)

plants at present, while large plants are still under construction.

As soon as sufficiently heavy copper bands can be produced more economically from powder than from ingots, the production of wire by powder metallurgy will become a practical proposition, because these bands can be cut into narrow strips which at first have a rectangular section, but are then drawn to fine wire of round section. This process offers the advantage of producing any required length, without the necessity for welding together separate lengths—an important factor in production. Also, a relatively large number of wires can be produced simultaneously in such a process, so that several wire-drawing machines can be fed from one rolling mill.

NORWAY

Measurement of Hydrodynamic Pressure on Ship Models

By H. CHRISTENSEN and J. E. FUNDER. (From *Teknisk Ukeblad*, Vol. 101, No. 25, June 24, 1954, pp. 561-565, 8 illustrations.)

IN ships, vibrations of the hull can occur from the action of the propeller. The wake of a ship gives rise to inhomogeneous conditions, and the propeller blades are therefore subjected to variable loads during their rotation. As a result, fluctuating forces are generated, with a fundamental frequency obtained as the product of the propeller speed multiplied by the number of blades. These forces are transmitted to the hull through the propeller brackets and the stern tube and result in horizontal and/or vertical vibrations of the hull or parts thereof.

Furthermore, there is also a direct action of the propeller blades, since these, during their rotation, generate a variable hydrodynamic pressure, which acts on the rudder and the ship's hull, mainly in the vicinity of the propeller. This excitation also leads to vibrations of the hull when the pressure fluctuations are sufficiently large.

Various types of ships suffer from vibrations of unnecessarily large amplitude, attributable to the propeller. This is because, in such cases, preliminary investigations for vibration reduction have not been sufficiently extensive. Vibrations can be overcome only after clarifying the reasons for their occurrence. The problem is of importance, particularly for fast passenger vessels.

The present trend, therefore, is to provide ship-model basins with special instrumentation for indicating hydrodynamic pressure variations, with equipment suitable for use on ship models. Instrumentation designed for this purpose is as follows :—

PRESSURE CELL

The main element of the equipment is a pressure cell (Fig. 1), which is a pressure-sensitive device mounted on the side of a ship model and connected to various electronic circuits which record pressure as a function of time. The associated equipment comprises an oscillator supplying an input voltage to the pressure cell, an amplifier with a phase-sensitive detector, and a multiple-channel pen recorder.

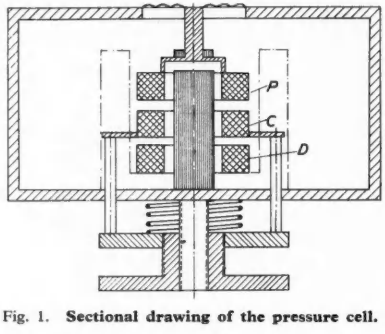


Fig. 1. **Sectional drawing of the pressure cell.**

In principle, the pressure cell operates as an open-circuit transformer, with variable coupling between two coils[1]. The cell is a brass cylinder, with an overall diameter of 80 mm and a height of 40 mm. The laminated iron core consists of mu-metal sheets of 0·004 in. in thickness. The driving coil (*D*) has 400 turns of wire of 0·2 mm diameter, and is supplied from the oscillator with an alternating voltage of 7 V at a frequency of 1000 cps. In this way, a magnetic field is generated in the cell, and any voltage induced in the pick-up coil (*P*) will be dependent on the distance of the latter from the driving coil. The pick-up coil is made up of 1000 turns of wire of 0·09 mm diameter. The pressure-sensitive component is a small diaphragm mounted on the pick-up coil. This diaphragm is a corrugated disc of beryllium copper. This material is extremely suitable because of its high elastic strength and stability. The diaphragm has a diameter of 30 mm and is 0·1 mm in thickness. These dimensions, according to calculations[2], correspond to a deflection of 0·001 mm for a pressure of 0·001 atm. This sensitivity was subsequently confirmed experimentally.

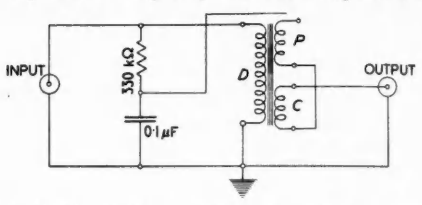


Fig. 2. **Circuit diagram of pressure-cell components.**

A third coil (*C*) is located between the pick-up coil and the driving coil, and is coupled with the former. The total voltage across the two coils, which is the output voltage of the pressure cell, should have a zero value at a certain position of the compensating coil (*C*) relative to the other two coils. However, complete compensation is not attained, because there is a small phase shift between the two voltages. This leaves, therefore, a residual voltage with a 90 deg. phase shift, which amounts to about 50 mV, according to measurements. To cancel this out, a corresponding compensating voltage is obtained from a condenser, as indicated in Fig. 2, which shows the connections between the various components of the pressure cell. The minimum voltage then obtained is 1·5 mV. As this voltage is 90 deg. out of phase relative to the signal voltage, it

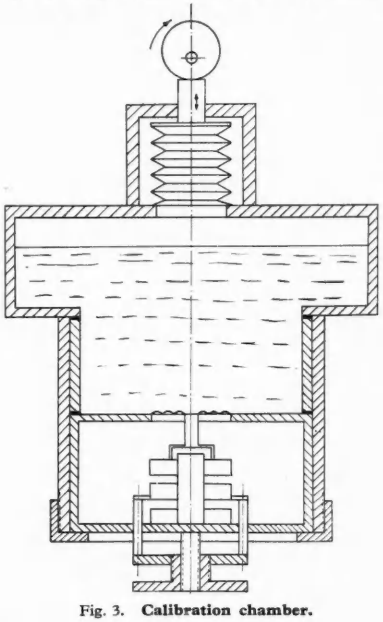


Fig. 3. **Calibration chamber.**

will not be present in the output from the phase-sensitive detector to the recorder.

When measurements are made on a model hull, the pressure cell is exposed to hydrostatic pressure, corresponding to the depth of immersion below the surface of the water. To achieve high sensitivity, it is necessary to be able to balance out this hydrostatic pressure, since it may be many times greater than the small pressure variations which are to be indicated. The compensating coil is therefore designed so that it can be adjusted to an appropriate position. The balance position is usually chosen so as to obtain zero deflection when the cell is subjected to hydrostatic pressure only.

Electronic Equipment

Electronic equipment comprises an amplifier with a low-pass filter having a limiting frequency of 1500 cps at the input. The phase-sensitive detector is of conventional design. The reference voltage is taken from the oscillator, which also supplies voltage to the driving coil. A multi-channel recorder is coupled to the anode circuit. Using four pressure cells, it is thus possible to record pressure variations simultaneously at four different positions on a model hull. The amplification is linear within a certain measuring range.

Calibration Tests

The cell was first subjected to static tests with pressures up to 0·5 m of water. It was found that the deflections of the pressure cell are substantially proportional to pressure. At maximum gain, the sensitivity is 1·2 mm deflection on the recorder diagram per centimetre of water pressure.

The pressure cell was then tested dynamically with

(*Concluded on page* 449).

Cost Accountancy in the Engineering Industry

By S. Howard Withey, F.B.S.C.

PART III

INTEREST ON CAPITAL AS A FACTOR IN ENGINEERING COSTS

Although engineers do not need reminding that industry is expected to limit the amount of new capital outlay in order to narrow the import-export gap still further, it is evident that in the near future considerable funds will have to be raised for purposes of re-equipment, modernisation, and development; consequently, an important factor to be taken into consideration when computing the charges to be included in cost and contract accounts is likely to be interest on capital. To ignore continually the incidence of interest in the assessment and recording of depreciation of engineering equipment sometimes leads to a state of affairs in which the margin of profit actually realised in the fulfilment of contracts proves to be insufficient to enable the management to set aside adequate sums for the renewal and replacement of units of plant, by reason of faulty estimates and quotations; this usually causes a serious shortage of working capital and exerts a retarding influence on processes of re-equipment. In all instances where funds are raised for the specific purpose of acquiring and installing new or additional groups or sections of equipment, it is advisable to make full provision in estimates and costs for interest on the amount of capital expenditure involved; failure to do this not only detracts from the practical utility of engineering and costing data, but may easily have unexpected and disastrous consequences.

When plans are being developed and operations mechanised with the aid of issues of debentures or share capital carrying dividends or annual interest at a fixed rate, the book values of the fixed assets may be increased temporarily by the addition of an appropriate percentage, enabling the total cost to be allocated over a definite period in the form of equal annual instalments. In this way, the engineering operations carried out during the service or useful life of the productive equipment may be charged with the full and proper cost and the amounts of annual interest credited separately to profit and loss or transferred to a reserve or other suitable account.

In a recent case, for example, the directors of an engineering company were faced with the necessity of raising the sum of £150,000 for the purpose of acquiring more modern sections of plant and mobile equipment. There were no outstanding loans, mortgages, or debentures, and the ordinary shares of the company entitled the holders to an unlimited proportion of the disposable surplus after meeting all prior claims. Arrangements were made for the issue of 150,000 cumulative preference £1 shares at par, giving the right not only to a fixed dividend of 5% in any one year, but also to any dividends which might fall in arrear, such arrears to be carried forward until paid off. When the subscription lists had been closed, details of the share capital were recorded in share books, the private ledger containing accounts summarising the share-ledger entries, and it was decided to allocate the proceeds from the issue as follows :—

	£
Furnaces, boilers, and receivers	85,000
Engines, electric motors, etc. ..	42,000
Automatic control gear, including instruments for indicating and controlling pressure, and other process variables	23,000

The existing equipment was re-allocated and, as it was the intention to include interest on capital at the rate of 5% in all future contract accounts, it was desired to effect this by spreading the new capital outlay and interest over a period of 20 years in such a way that, at the end of that period, the book values of the equipment will approximate to the following figures :—

	£
Furnaces, boilers, and receivers	37,000
Engines, electric motors, etc. ..	11,000
Automatic control gear, etc. ..	2,000

This meant that, in the case of the furnaces, boilers, and receivers, the sum of £48,000 would have to be written off over the nominated period of 20 years, this being the equivalent of the original capital cost *minus* the estimated residual value; to simplify the accounting, it was decided to write off a fixed amount each year for incorporation in the costings *after* adding interest at the rate of 5% to the diminished book value of the equipment.

In this case, the precise amount to be charged against each year's operations was determined by compiling a table giving the decimals needed to extinguish £1 over varying periods, after charging interest at specific rates. From this table, the decimal required to extinguish £1 over 20 years at 5% is 0·080243. Multiplying this decimal by 48,000 (representing the amount to be written off) gives £3,852 (to the nearest £1) as the amount to be written off each year. Against this will be set each year's interest at 5%, calculated on the balance remaining to be written off, as demonstrated in the following table :—

FURNACES, BOILERS, AND RECEIVERS.

Year	Balance remaining to be written off	Interest at 5%	Total Debit	Amount written off	Carried forward
	£	£	£	£	£
1st	48,000	2,400	50,400	3,852	46,548
2nd	46,548	2,327	48,875	3,852	45,023
3rd	45,023	2,252	47,275	3,852	43,423
4th	43,423	2,172	45,595	3,852	41,743
5th	41,743	2,088	43,831	3,852	39,979
6th	39,979	2,000	41,979	3,852	38,127
7th	38,127	1,907	40,034	3,852	36,182
8th	36,182	1,810	37,992	3,852	34,140
9th	34,140	1,707	35,847	3,852	31,995
10th	31,995	1,600	33,595	3,852	29,743
11th	29,743	1,488	31,231	3,852	27,379
12th	27,379	1,370	28,749	3,852	24,897
13th	24,897	1,245	26,142	3,852	22,290
14th	22,290	1,115	23,405	3,852	19,553
15th	19,553	978	20,531	3,852	16,679
16th	16,679	833	17,512	3,852	13,660
17th	13,660	683	14,343	3,852	10,491
18th	10,491	524	11,015	3,852	7,163
19th	7,163	358	7,521	3,852	3,669
20th	3,669	183	3,852	3,852	Nil

The total amount written off over the period will be £77,040, i.e., 20 × £3,852, of which a total of £29,040 will represent interest, thus :—

Debit	FURNACES, BOILERS, AND RECEIVERS A/C			Credit
	£			£
To Capital Cost ..	85,000	By Amount written off		77,040
To Interest ..	29,040	By Balance c/down ..		37,000
	£114,040			£114,040
To Balance b/down	£37,000			

In the case of the engines and electric motors, etc. it will be necessary to reduce the book value by £31,000 ; consequently, the amount to be included in the costings after charging interest was determined by multiplying the decimal 0·080243 by 31,000, giving £2,488, the total amount to be charged against the periodical profits being £49,760, including annual interest items aggregating £18,760, the latter being calculated at 5% of the balance remaining, in the same way as for the furnaces, boilers, etc., thus :—

Debit	ENGINES, ELECTRIC MOTORS, Etc. A/C			Credit
	£			£
To Capital Cost ..	42,000	By Amount written off		49,760
To Interest ..	18,760	By Balance c/down ..		11,000
	£60,760			£60,760
To Balance b/down	£11,000			

Similarly, in order to cover depreciation in the capital value of the company's automatic control gear and instruments from £23,000 to a nominal £2,000, an amount of £1,685, i.e., 0·080243 × 21,000 will have to be written off each year, making a total of £33,700 for the 20-year period of service life, of which £12,700 will represent interest at 5%, calculated on each year's reduced book value, thus :—

Debit	AUTOMATIC CONTROL GEAR A/C			Credit
	£			£
To Capital Cost ..	23,000	By Amount written off		33,700
To Interest ..	12,700	By Balance c/down ..		2,000
	£35,700			£35,700
To Balance b/down	£2,000			

To ensure increased productivity, to reduce costs, and to improve the quality of products, several engineering concerns have taken up investments outside the business, calculated to secure a definite sum at a definite date. At the end of 1952 the equipment employed by one of these firms had a balance-sheet value of £10,000, and it was decided to pay an annual premium each year, commencing in January 1954, for the purpose of securing £10,000 in ten years. The precise amount of annual premium required to effect this was ascertained by referring to a table giving the decimals needed to produce £1, after allowing for interest at varying rates. From this table, the decimal required to produce £1 over 10 years at 5% is 0·079505. The amount of annual premium was determined by multiplying this decimal by 10,000, giving £795. These payments will be posted direct from the firm's cash book to the debit side of an Investment Account, which at the end of ten years will show the following figures :—

Debit	INVESTMENT A/C			Credit
1954	£			£
Jan. To Premium ..	795	By Balance c/down ..		835
Dec. To 5% Interest	40			
	£835			£835
1955				
Jan. To Balance b/down	835	By Balance c/down ..		1,712
Jan. To Premium ..	795			
Dec. To 5% Interest ..	82			
	£1,712			£1,712
1956				
Jan. To Balance b/down	1,712	By Balance c/down ..		2,632
Jan. To Premium ..	795			
Dec. To 5% Interest ..	125			
	£2,632			£2,632
1957				
Jan. To Balance b/down	2,632	By Balance c/down ..		3,598
Jan. To Premium ..	795			
Dec. To 5% Interest ..	171			
	£3,598			£3,598
1958				
Jan. To Balance b/down	3,598	By Balance c/down ..		4,613
Jan. To Premium ..	795			
Dec. To 5% Interest ..	220			
	£4,613			£4,613
1959				
Jan. To Balance b/down	4,613	By Balance c/down ..		5,678
Jan. To Premium ..	795			
Dec. To 5% Interest ..	270			
	£5,678			£5,678
1960				
Jan. To Balance b/down	5,678	By Balance c/down ..		6,797
Jan. To Premium ..	795			
Dec. To 5% Interest ..	324			
	£6,797			£6,797
1961				
Jan. To Balance b/down	6,797	By Balance c/down ..		7,972
Jan. To Premium ..	795			
Dec. To 5% Interest ..	380			
	£7,972			£7,972
1962				
Jan. To Balance b/down	7,972	By Balance c/down ..		9,205
Jan. To Premium ..	795			
Dec. To 5% Interest ..	438			
	£9,205			£9,205
1963				
Jan. To Balance b/down	9,205			
Jan. To Premium ..	795			
	£10,000			

The items of interest debited to the investment account will be posted direct to the credit side of a sinking-fund account, which will also be credited with the amount of each annual premium, the latter being charged against the profits, in lieu of the customary charge for depreciation of equipment. Upon realisation of the investment, the sum of £10,000 will be posted from the firms cash book to the credit side of the investment account, which will then be ruled off. During the entire period, the balance of the equipment account will remain unaltered and, at the termination of the 10-year period, the sinking fund will total £10,000, the invoiced cost prices of the new equipment being capitalised in the usual way.

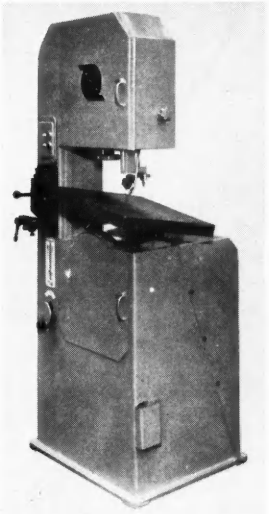
(To be concluded).

New Materials, Processes and Equipment

TOOLROOM BANDSAW

The "Midsaw Minor" toolroom bandsaw, manufactured by The Midland Saw & Tool Company Limited, of Birmingham, is of substantial design and neat appearance, and offers a speed range of from 60 to 500 fpm. The table, which measures 18 × 18 in., is accurately machined and cants four ways, i.e., 45 deg. right, 15 deg. left, and 15 deg. front and back. Gauges, showing the degree of cant, are provided. A positive locating mechanism is incorporated, as well as locking handles.

The machine is driven from a single-speed motor *via* a double variable-pitch V-rope pulley to the input shaft of a totally enclosed gearbox. A speed indicator is fitted to the front of the machine. Saw wheels are of cast iron, with vulcanised-rubber treads, and are interchangeable. Two saw guides are fitted as standard equipment, one above and one below the table. The top guide is adjustable vertically from table level to 8 in. above the table. Both guides are arranged for horizontal adjustment. A centrifugal air pump is located in the base of the machine, and is driven by the motor.

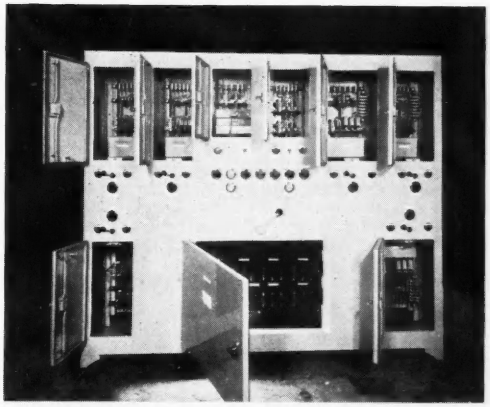


A flush-mounted brazer is fitted as standard, and is suitable for saws up to $\frac{5}{8}$ in. in width. A cam-operated clamp, for holding the saw while the joint is being finished, is provided on the brazer panel.

ELECTRICAL CONTROL GEAR

Control gear of the air-break type, of much improved design, in a range of 10 to 1400 A, marketed by G.W.B. Furnaces Limited, of Dudley, Worcs., are claimed to have many technical advantages over conventional gear with copper contact faces. This design of gear has been developed by the firm of Officine Meccaniche Riunite, of Milan.

The heart of any form of electrical control gear is the contactors themselves. G.W.B. are using sintered tungsten-silver exclusively for the contact faces, and it is claimed that this type of contact face has a life of up to 20 times that of conventional copper contacts. The use of this type of sintered contact eliminates de-rating of the contactor, which normally occurs in the case of copper contacts as the number of hourly operations is increased. Furthermore, sintered tungsten-silver contacts are virtually unaffected by oxidation or corrosion under atmospheric conditions normally considered unfavourable for contactor use. This property renders them eminently suitable for marine applications and for certain industrial uses.



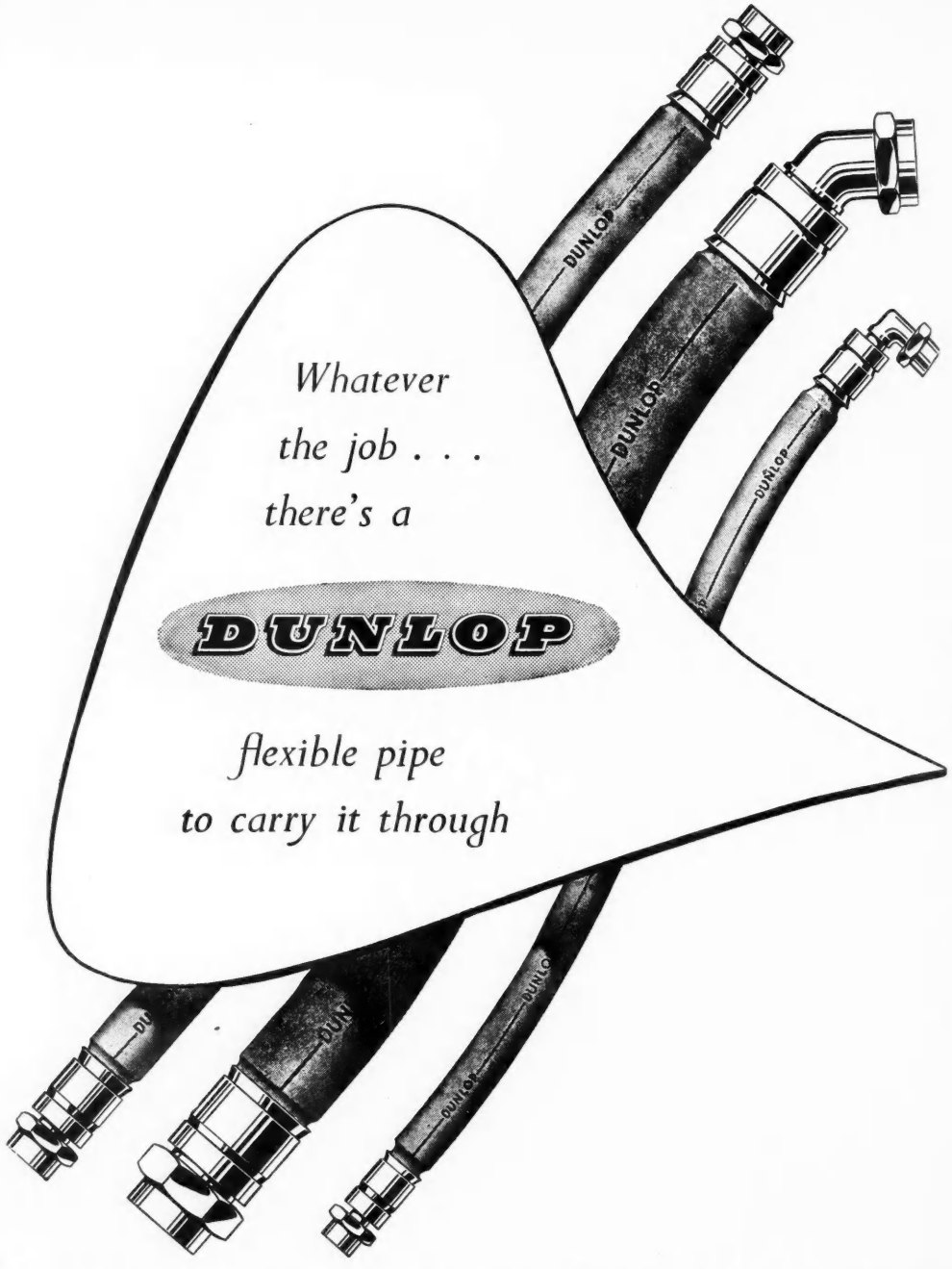
All G.W.B. contactor gear is of unit construction, thus simplifying assembly and maintenance, while any subsequent alteration in the contactor assembly set-up can normally be carried out with little trouble. The moving arm is of insulated steel of rectangular cross-section, turning on hardened conical bearing points at each end. Tests of long duration have indicated no appreciable wear after more than 10,000,000 operations. Slight tension is applied during assembly of the moving arm, so that there is automatic take-up adjustment. All G.W.B. control panels incorporate this contactor gear, and all parts are accessible from the front, so that dismantling and replacement can be effected without the necessity of stripping down the contactor. The various component parts of the contactor assembly are easily mounted onto the moving arm, without the necessity for removing the main support.

The illustration shows a large multi-motor panel supplied to a well known rayon manufacturer, for shredding-process sequence control of artificial fibre.

DRIP-FEED GAS-CARBURISING PROCESS

Drip-feed systems of gas carburising are not new and are well known to involve the production of carburising atmospheres directly within the furnace chamber. A new system evolved by Wild-Barfield Electric Furnaces Ltd., of Watford, Herts., features the use of a liquid known as "Carbodrip," which is the subject of a patent application.

It should be understood that the Wild-Barfield drip-feed gas-carburising process does not in any way supplant the original Wild-Barfield Prepared Town's Gas process ("P.T.G."), which has been operating successfully for some twelve years; on the contrary, the new process is, in effect, complementary to "P.T.G." and, while all the advantages of the latter system are retained, the "Carbodrip" system has the following additional points of merit:—No supply of town gas is required; the apparatus covering the pro-



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cess is extremely simple to operate and does not require skilled supervision ; " Carbodrip " is entirely free from deleterious sulphur compounds ; floor space is reduced to a minimum, as there is no separate gas plant, as such ; for any given size of installation, the capital cost on the gas-producing side is much lower, and, as there is no gas-producing unit, power costs are reduced ; " Carbodrip " is low in price, compared with other drip-feed media ; maintenance costs on the atmosphere-producing equipment are negligible, being limited to ensuring an adequate supply of drip-feed liquid.

Equipment comprises a vessel with a usable capacity of ten gallons of " Carbodrip." It is fitted with a well protected liquid-level glass, a pressure gauge, a filler cap, and a safety or relief valve. The liquid is fed into the carburising furnace by the action of compressed air, which activates flow *via* a liquid filter, a fine-control needle valve, and an indicating flowmeter. Most establishments normally have a supply of compressed air available at pressures of the order of 50 to 100 psi ; in such cases, all that is needed is a small water trap and a pressure reducing valve, to lower the line pressure to between 5 and 10 psi. If a works supply of compressed air is not available, a small portable compressor and capacity vessel will suffice.

The carburising furnaces are of standard vertical-retort type, and incorporate a liner which has a positive clamped seal at the top and a chrome-ore seal at the bottom. The top, constituting seal and door, is raised by means of a power-operated hydraulic ram. Efficient gas circulation is ensured by a powerful centrifugal fan provided at the base of the furnace and working in conjunction with an inner drum, located centrally on a specially designed throat casting.

" Carbodrip " carburises in exactly the same way as " P.T.G.", i.e., at nearly the maximum theoretical rate for any given steel at a given carburising temperature. Consequently, for any specified size of carburising installation, the output will be higher than that of a comparable size of equipment fed by other drip-feed systems ; furthermore, as " Carbodrip " is low in cost, compared with other drip-feed media, the cost per pound of work treated will be lower.

MAGNETIC FATIGUE TESTER

One of the machines now being used for research into the endurance limits of steels at U.S. Steel's Research and Development Laboratory, Pittsburgh, is a magnetic fatigue tester. Samples of steel, from 24 to 36 in. in length, up to 2 in. in thickness, and 5 in. in width, can be subjected to controlled vibrations at the natural frequency of the testpiece.

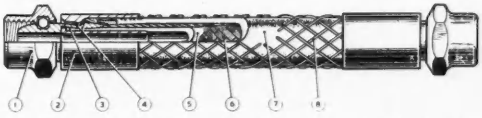
The machine consists of two rubber-padded supports, upon which the testpiece is placed ; an electro-magnet located at each end of the tester ; pick-up coils, located at the centre of the sample ; a power unit with controls ; a stroboscopic light ; and a micro-comparator, to measure vibration amplitudes. A piece of steel, which must be long enough to extend over the two end magnets, is placed on the supports, and the end magnets are positioned under the ends of the sample. An alternating current is then supplied to the magnets, to set the steel vibrating. Each experimental section has a natural frequency at which it will vibrate, the natural frequency depending on the dimensions of the piece. The centre pick-up coils translate the motion into electrical impulses, which feed back to the power unit at the natural frequency of the sample. These impulses control the pulsations of electricity from the power unit to the end magnets, so that they match the frequency of the specimen and keep it vibrating. The amplitude of the vibrations of the sample depends on the intensity of the current supplied to the end magnets.

When a crack develops in the test specimen, its natural vibrational frequency changes. This change upsets the rhythm of impulses from the pick-up coils to the power unit and the machine automatically stops. By use of the micro-comparator, the amplitude of the vibration or the amount of bending can easily be measured.

The stroboscopic light is used to establish the location of very small fatigue cracks. This is effected by adjusting the light from the stroboscope to a frequency slightly higher or slightly lower than that of the vibrating sample, so that the testpiece appears to be bending very slowly, thus enabling its surfaces to be carefully examined for very small cracks.

FLEXIBLE PIPE UNITS WITH REINFORCED PLASTIC TUBING

A plastic pipe unit which can successfully withstand the severest conditions demanded by various industries is announced by Bowden (Engineers) Limited, of London, N.W.10.



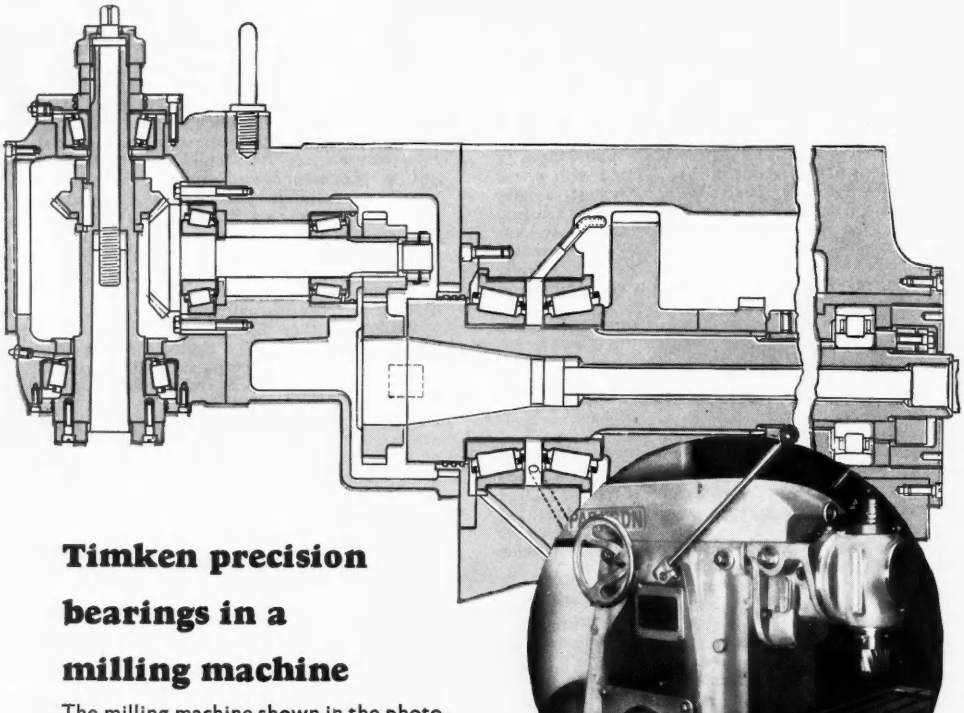
These Bowdenflex pipe units incorporating reinforced plastic tubing are offered in a wide range, covering complete pipe units up to bursting pressures in excess of 10,000 psi. The problem of differing conditions inside and outside the pipe has been successfully solved. For conveying acid, gas, air, or any type of fluid, an inner plastic tube (5), as shown in the illustration, is selected and is reinforced with wire braiding (6), to withstand the pressure required. An outside tube (7) may then be fitted, to resist external factors, such as fire, and, if necessary, an additional wire braid (8) may be introduced over the outside tube as a protection against abrasion or rough treatment.

The new process is used in conjunction with a thrust-wire nut (1) and the already well known Bowden, Series 2000, patented swaged coupling (2), with a lip seal (3) and wire-braid interlock (4).

15-TON HYDRAULIC PRESS

A new 15-ton hydraulic press, designated Model 4, is announced by Pilot Works Ltd., of Bolton. This press has a daylight of 16 in., with a throat of 8½ in. and a stroke of 8 in., and is operated by a 4-hp motor running at 950 rpm. For a full 8-in. stroke, the operating speed is 2½ seconds down and 1½ seconds up.

Ram pressure is adjustable between one and fifteen tons, by operation of a small handwheel. The ram is 2½ in. o.d., with a tool socket 1 in. × 2½ in. in depth. Reliable oil sealing is provided by four piston rings, and a 2-in. o.d. guide bar is firmly linked to the main ram. The pump is of " Pilot " design and is of the twin-



Timken precision bearings in a milling machine

The milling machine shown in the photograph is made by J. Parkinson & Son (Shipley) Ltd., Yorkshire, and the line drawing shows the vertical attachment in place with its drive and the bearings employed. The spindle of the 'vertical' attachment, which can be swivelled at an angle if required, is carried in two Timken 'Precision 3' tapered-roller bearings, pre-loaded by the adjustment shown at the top. This spindle is bevel-driven from a horizontal shaft carried in two standard Timken bearings, and is itself driven by a gear wheel carried in the main spindle.

This main spindle is carried at the nose-end in a pair of Timken 'Precision 3' flanged bearings: these bearings give a very rigid mounting, meet thrust loads from both directions, and by reason of their close relationship are unaffected in their pre-loading by the differential expansion of housing and spindle. They are oil-lubricated.

With these shouldered bearings the housing for the two is bored as one, ensuring concentricity. Other radial support, with freedom for axial expansion, is provided by a parallel-roller bearing at the tail end.

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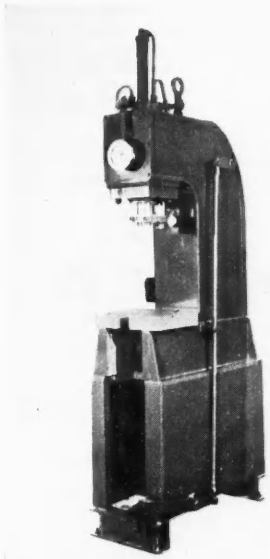


cylinder, plunger type, with an oil tank of 6 gallons capacity. The high-pressure fluid circuit is fully protected by a special overload valve. Increased operating speed is obtained by a power-return stroke for the ram. Operation of the press is simply effected by means of two foot controls, one for the up movement and the other for the power return. Speed is variable and is controlled by the pressure applied by the operator.

The new press is extremely compact, occupying a floor space of only 17 × 34 in., overall height being 7 ft 2½ in. The weight is about 1400 lb. Great attention has been paid to ease of maintenance, all parts being readily accessible.

ERASABLE TYPEWRITING PAPER

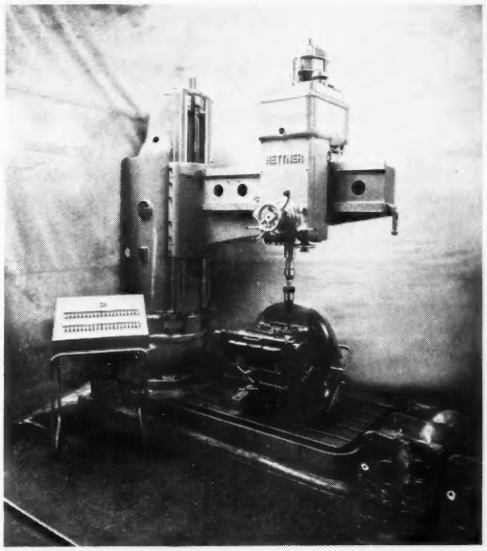
A rag-content paper, which combines the quality of a superior typewriting and printing paper with virtually complete and extremely easy erasability, has been developed by the Hemlock Paper and Envelope Co., of Bayonne, New Jersey. An ordinary soft pencil eraser can be applied to any typing error on this paper and, with a very few light strokes, the error rubs out cleanly, without leaving any "ghost" or scuff marks.

Hemlock Erasable Paper, as it has been designated, is made up in all popular weights in sizes, in white only. It can be printed in the same way as ordinary papers and is perfectly suitable for letterheads. Although fully erasable, it does not deteriorate or discolour any more quickly than conventional rag-content paper. Typing will not fade or smear unduly, although it is desirable to use a medium-inked typewriter ribbon with it and a medium-finish carbon paper for copy work.

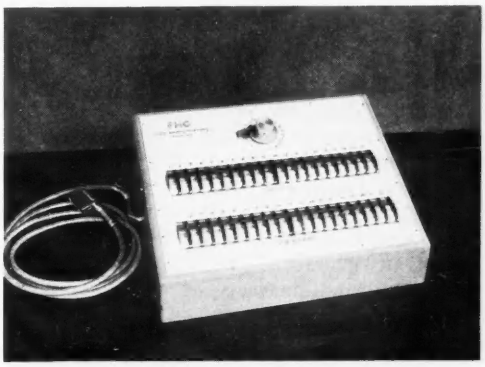
Samples of this paper have been received at this office and erasability tests have fully substantiated the makers' claims.

RADIAL DRILL WITH PRESELECTOR SYSTEM

A radial drilling machine, incorporating a special preselector system, was exhibited at the recent Fourth European Machine Tool Exhibition, Milan, by Hettner, of Münstereifel, Germany. This system enables spindle speeds and feeds to be preselected for a range of operations on one or more components, the sequence being subsequently repeated automatically. Operation of the machine can therefore be entrusted to semi-skilled personnel.



The selector panel, which is shown in close-up below, and which can also be seen at the left of the illustration above, is of simple and compact construction and includes an indicator showing the number of the operation stage in progress. Individual stages can be repeated or by-passed, or the preset sequence can be interrupted entirely and replaced by individually selected feeds and speeds. The system is operated by a combination of electrical, hydraulic, and mechanical equipment, and is virtually foolproof. Machine controls are simplified to a minimum, one lever being used for controlling starting of the operational sequence, direction of spindle rotation, and operation of the spindle brake, while one push-button controls the electro-hydraulic locking of the drilling head and the outer column.



An automatic tapping cycle is also provided, and this consists of forced feed at the required rate, automatic spindle reversal at a preset depth, and a reverse speed, equivalent to twice the forward speed. The machine is capable of drilling up to 55-mm diameter in steel, and is provided with 23 geometrically stepped speeds, ranging from 12 to 2000 rpm, and 19 feeds, similarly stepped, ranging from 0·08 to 3·5 mm per revolution.

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Great savings in tool wear and lubricant costs are frequently made by the use of Esso T.S.D. 404—a unique new soluble oil with remarkable extreme pressure properties resulting from an active chlorine additive.

In one case recently where an entire section of a machine shop was engaged in tapping stainless iron, T.S.D. 404 replaced a conventional soluble oil with a 750% increase in tap life. This meant a great saving in costs and an increase in production. The emulsion of T.S.D. 404 caused no skin troubles in use and its non-corrosive properties were found entirely satisfactory.

In another case a well-known factory producing aero engines tested a 20:1 emulsion of T.S.D. 404 against the heavily sulphurised straight cutting oil that it had been using in the slab milling of nimonic aviation gas turbine blades. The resulting improvements in cutter life ranged from 50% to 80% and there was a big saving in cost, since the price of the emulsion was about 4½d. per gallon, instead of 13/- for the straight oil. Moreover, the machine operators found the emulsion entirely free from objectionable odours and much cleaner to use.

These examples show the type of saving and improvement in production and efficiency that can often be achieved by using the wide range of Esso Industrial Lubricants. There is a product specially suited to every industrial need and advice on their use will be freely given without obligation. Why not let us arrange for one of our Technical Representatives to call and discuss your particular problems?

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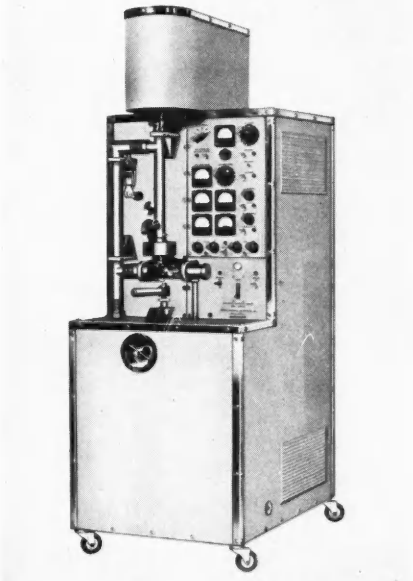
HIGH-SPEED MICRO-OSCILLOGRAPH

Proportionally higher cut-off frequency for a travelling-wave deflection system is one of many features of a new high-speed micro-oscillograph manufactured by Central Research Laboratories, Inc., of Red Wing, Minnesota. Designated "Model 2," this instrument is suitable for the single-sweep recording of three simultaneous phenomena at frequencies up to 10,000 megacycles and may be used whenever detailed information on phenomena occurring in time intervals of 10^{-8} to 10^{-10} sec is desired.

Three beams and three completely shielded, independent, electrostatic deflection systems are provided. The electron beams are focused to writing spots of 0·01-mm diameter by an electromagnetic lens, in which the coil current is regulated to better than 0·05%. Oscillographs are thus reduced in size by a factor of 100, compared with normal-size records with a trace width of 1 mm.

Records are made by a single-sweep tracing directly on the photographic plate, which is inserted into the vacuum chamber through a vacuum lock. Removal of an exposed plate, insertion of an unexposed plate, and establishing an operating vacuum are stated to require less than 5 minutes. Plate dimensions permit 27 oscillograms to be recorded on a single plate, with no overlapping, and enlargements up to 100 diameters may be made.

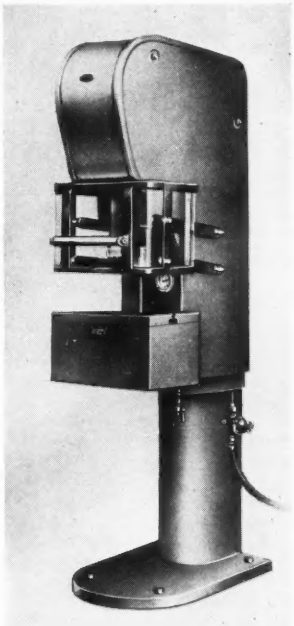
The signal-axis deflection systems consist of short lengths of specially designed vacuum-dielectric coaxial lines, in which the velocity of propagation is matched to the electron velocity at 50 kV. The time-axis deflection systems consist of parallel plates, one of which is grounded, the lead to the other being brought in through the same type of connector as for the signal axis. At 50 kV, the deflection factor for the signal axis is approximately 0·2 V per trace width, and for the time axis approximately 6·5 V per trace width.



Using an easily replaceable, hairpin, tungsten filament as the cathode, the electron gun is of the Wehnelt-cylinder, hot-cathode type. Its beam-accelerating potential is adjustable in 10,000-V steps up to 50,000 V, and is regulated to better than 0·05%. During stand-by, the electron gun is biased beyond cut-off, so that the photographic plate will not be fogged by scattered and secondary electrons. Vacuum is maintained by a pumping system consisting of an oil-diffusion pump backed by a two-stage mechanical pump. The instrument is also equipped with an ionisation gauge and a thermocouple gauge for pressure measurement.

PNEUMATIC PRESSES

The new range of pneumatic presses manufactured by James Holt (Engineers) Ltd., of Bolton, Lancashire, includes 600-lb, 1-, 3-, and 5-ton models.



The 600-lb bench model is designed for light workshop pressings and covers a wide range of operations. The 1- and 3-ton models are compact bench-mounting units, designed for hand or foot operation. They will perform all standard pressing operations in the workshop and may also be used for riveting and peening, when fitted with a vibrator.

The 5-ton press (illustrated) operates up to 5 tons at 80 psi, and is readily adaptable for blanking, piercing, and forming of stampings.

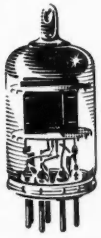
MICROFORM GRINDER

A new microform grinder, model No. 123, manufactured by The Sheffield Corporation, of Dayton, Ohio, will grind cylindrical work and circular form tools up to 8 in. in diameter and 8 in. in length, and can be used to grind forming, beading, and seaming rolls. Designed to be used for circular grinding only, this special-purpose machine is accurate, economical, and easy to operate. It permits finish-grinding directly from a drawing, requiring neither templates nor masters, and can be supplied with either live- or dead-centre workheads. The pantograph has a ratio of 50 to 1, and the drawing table will accommodate a 20 × 20 in. drawing.

In addition to grinding work up to 8 in. in diameter and 8 in. in length, work up to 10 in. in diameter and 9 in. in length can be swung between centres. The maximum-size grinding wheel used is 7 in. Neither the spindle nor the workhead needs to be adjusted

PROGRESS IN ELECTRONICS

The modern fighter aircraft is a machine of great complexity. It is required to execute startling manoeuvres at supersonic speeds and at high altitudes. Apart from the skill of the pilot, its operation, its safety and even its performance depend to a very large extent upon a variety of electronic devices and apparatus.



A normal fighter is provided with radio and inter-communication equipment; with navigational aids and radar; with altimeters and other electronic instruments; and with servo-amplifiers for automatic control and regulation. In all this apparatus something like 150 radio valves of different types are employed, and they must be capable of withstanding conditions of exceptional stress and vibration.

To satisfy these abnormal requirements, Mullard have developed a range of Special Quality Valves which, besides conforming to the most exacting specifications, can be economically produced in quantity. Entirely new techniques of design and manufacture have been evolved to achieve this, and these in themselves represent a notable advance on anything yet developed on either side of the Atlantic.

The background to Special Quality Valves and other outstanding Mullard developments is a growing research organisation and continuously expanding manufacturing resources, important contributions to Britain's progress in electronics.

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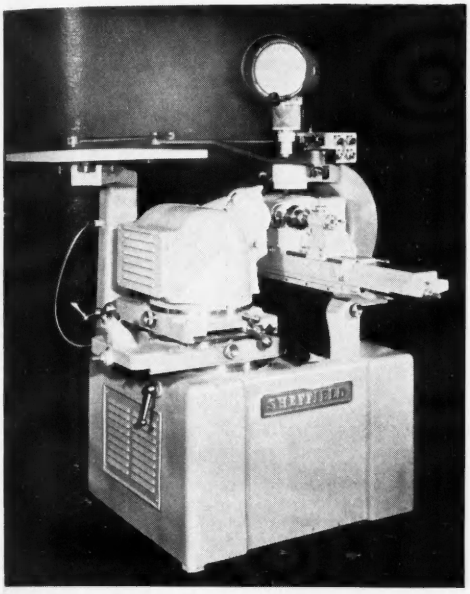

vertically, as both are in a fixed plane.

The wheelhead is driven *via* a V-belt by a 1-hp, 1725 rpm, ball-bearing motor and provides a spindle speed of 3000 rpm. The gear-driven workhead, equipped with change gears, is powered by a $\frac{1}{4}$-hp, 1800 rpm motor, providing workhead speeds from 40 to 360 rpm.

HYDROSTATIC DUST COLLECTOR

A new type of dust collector has been added to the present range of patent " Multiswirl " models manufactured by Dallow Lambert & Co. Ltd., of Leicester.

Previously available in the MSE series and applied in the main as an individual unit for fettling booths, double-end polishers, and grinders, the new series ME is available to handle large volumes of air and heavy dust concentrations. This series, which employs the Dallow Lambert patent hydrostatic cross-tube element, scrubs dust-laden air in either water or oil.

Of modern, streamlined design, this compact unit attains a very high separation efficiency, has a high air-volume to cost-and-space ratio, and operates without either pumps or sprays. It is eminently suitable for the chemical trade in its widest applications, for all types of explosive dusts, for foundry work, for sanding operations, etc., special safety features being afforded for the handling of explosive materials.

The illustration shows model ME. 10/9, designed as a complete unit to handle 1000 cfm. A hand-controlled valve permjts sludge removal on this model.

PRINTED-CIRCUIT GEIGER COUNTER

What is claimed to be the first commercially available Geiger counter employing a patented printed circuit is announced by The Radiac Company, of New York. Known as the " Prospector," the device utilises miniaturised components, an electronic high-voltage supply, operating on standard low voltage batteries, and a standard-size Geiger tube, built into the case for physical protection. The case is made of drawn aluminium and has a contoured non-slip handle, which not only affords a comfortable hand-grip, but also permits the instrument to be hooked onto a belt, leaving the hands free for other purposes.

The " Prospector," which weighs only $2\frac{3}{4}$ lb, features three methods of indication, i.e., audio, flashing neon light, and meter, with sensitivity ranges of 0·2, 2·0, and 20 mr/hr, full-scale reading. The neon light is located on the meter face, thus giving concentrated visual indication. The instrument, which detects beta particles and gamma rays, was designed and developed as a lightweight, ultra-sensitive Geiger counter for radioactive ore prospecting.

HIGH-SPEED ELECTRONIC SWITCH

As many as ten synchronised sweeps can be thrown at one time on the screen of a single-gun oscilloscope with the aid of a new electronic device developed by Burroughs Corporation (Electronic Instruments Division), of Philadelphia, Penn. This compact unit, called a " multiplexer," was shown for the first time at the recent Western Electronic Show and Convention, Los Angeles.

Basically, the device is an ultra-high-speed electronic switch built around another new Burroughs product, the beam-switching tube ; it combines as many as ten input wave forms in a single, sequenced wave train, and then electronically chops the train into ten separate sweeps, which are positioned vertically down the face

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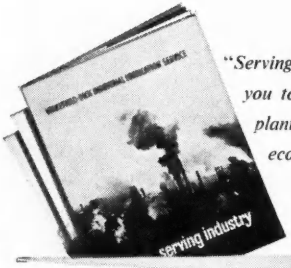

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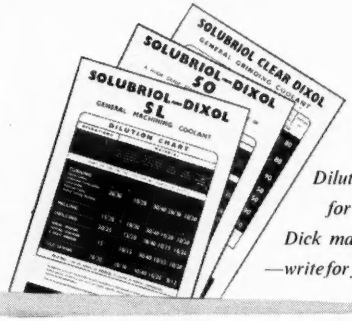

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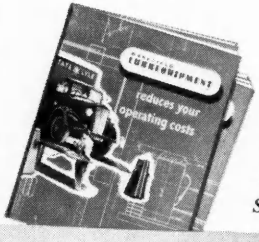

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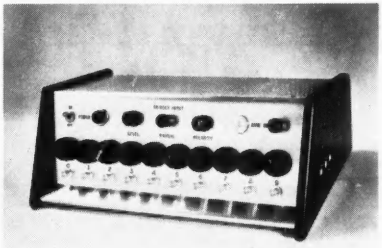
of a single-gun oscilloscope. Separate sweeps can be thrown onto the face of an oscilloscope in this way at the rate of 500,000 a second.

Possible uses are in strain-gauge analysis, to study stresses throughout a body; in television-receiver design, to study simultaneously the performance of video, audio, and related channels; and in medical electronics, to study the response under stimulation of various organs of the human body.



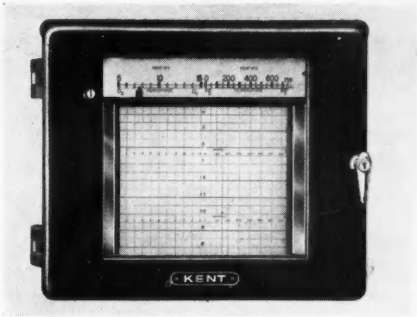
The information input section of the multiplexer will accept from two to ten different wave forms or pulse patterns. Each is fed to the grid of a separate triode amplifier. The plates or outputs of all ten tubes, which are normally not conducting, are tied together across a common load resistor. A separate external input, a synchronising signal from the subject under study, is fed to a Schmitt trigger input stage in the multiplexer. This circuit causes a beam-switching tube to trigger the triode amplifiers one by one. The resulting output across the common load resistor is a single wave train, containing in sequence all the input wave forms to be observed. Each wave form in the train, however, is at a different direct current level. As a result, when fed to the vertical deflection plates of a single-gun oscilloscope, each wave form is spaced separately down its face. The circuit can be set to fire at various points along a sine wave or rising d.c. wave front. In addition, for each successive position of the beam-switching tube, the Schmitt circuit feeds an output pulse to the oscilloscope to trigger a new sweep.

Front panel controls for each of the ten input amplifiers permit the user to vary the d.c. level of each separate wave form and thus position them at will down the face of the oscilloscope. Each control is a dual-section potentiometer which keeps the gain constant, though varying d.c. output level. The frequency response of the amplifiers is 3 decibels down at 40 cycles and one megacycle. Additional front panel controls include a push-button to step the output of the multiplexer manually from one sweep position to the next. Another push-button automatically resets the sweep to the zero position.

COMBINED OXYGEN AND TEMPERATURE RECORDER

A combined oxygen and temperature recorder, as an addition to their standard range of "Multelec" instruments, has been designed by George Kent Ltd., of Luton, Bedfordshire. The new instrument is the counterpart of their combined CO_2 and temperature recorder, but has the latest Kent magnetic oxygen analyser in place of a CO_2 analysis cabinet. This type of combined instrument is designed primarily for the boiler-house, where, by virtue of its side-by-side record of flue-gas temperature and analysis, it provides an easily read picture of stack losses. Other applications will, however, suggest themselves.

Stack losses naturally depend to a considerable extent on the quantity of excess air fed to the furnace. The oxygen analyser measures the oxygen concentration in the flue gases; this concentration bears a close relation to the quantity of excess air, and thus gives an

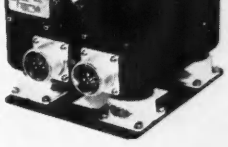


accurate record of combustion conditions. The optimum CO_2 content of flue gases can vary between wide limits for variations in fuel, resulting in a less accurate setting of the excess air delivered and consequent loss of efficiency. The response of the oxygen analyser is, moreover, considerably faster than that of a CO_2 analyser.

The recorder in the new instrument is of the two-point form, the change-over from one point to the other being entirely automatic. The oxygen record is on the left-hand side of the chart and the temperature record on the right. Two entirely separate measuring circuits are provided. The maximum range of oxygen in flue gas which can be accommodated is zero to 15%; the temperature circuit is of the three-wire resistance-thermometer type, with a standard range of 0° to 750° F. High instrument sensitivity, with a robust galvanometer system, is obtained by the use of the latest Kent vibrating-reed synchronous converter.

AIRCRAFT MACH-NUMBER COMPUTER

A new, lightweight, extremely accurate force-balance type of Mach number computer, designated the CA-500, and requiring no vacuum tubes, for use in commercial and military aircraft, is announced by Servomechanisms, Inc., of Long Island, N.Y. The new computer, which weighs only 4½lb and which measures approximately $5\frac{1}{2} \times 5\frac{1}{2} \times 4$ in. in height, provides an accuracy of 0·01 Mach for 95% of laboratory test points, and its design characteristics eliminate the need for external pressure transducers and vacuum tubes.



Features include simplicity, thus reducing maintenance and service to a minimum and increasing reliability; maximum versatility, in that the instrument, when combined with a temperature bulb and two local wind detectors, mounted in the air stream to supply local angle of attack and local angle of yaw, respectively, produces voltages proportional to true angle of yaw, Mach number, and true airspeed. Ample torque is available for driving an analogue-to-digital converter, to provide digital outputs, for which remote dial indications can be provided. Positioning function potentiometers may be utilised to provide information for auto-pilot gain adjustments or control-surface sensitivity.

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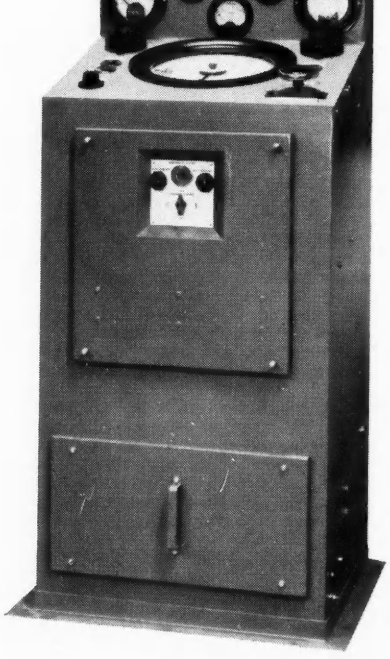

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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

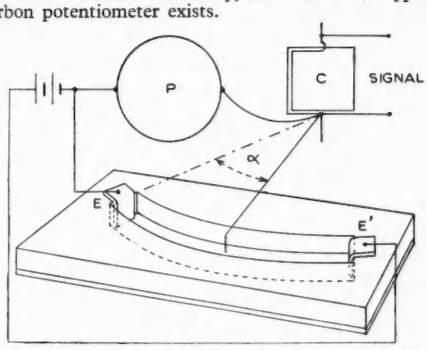
ELECTRICAL INSTRUMENTS

Fluid Amplifiers.

By M. ODIER. (From *Mesures & Contrôle Industriel, France*, Vol. 19, No. 207, August 1954, pp. 479-484, 7 illustrations.)

THE problem of amplification arises whenever a physical phenomenon involving an extremely small force must be measured, recorded, or regulated. Electronic methods of amplification are, of course, well known. In certain applications, however, they may not be considered entirely efficient. Thus, for example, a recording milliammeter may be required to record signals corresponding to a small fraction of a microwatt. A conventional electronic amplifier of adequate stability would consume several tens of watts, whereas the recording milliammeter itself may not require more than 10 milliwatts.

In the case of a simple needle-type millivoltmeter, for instance, it would be possible to provide direct operation of a recorder, without electronic amplification, if the pointer of the instrument could constitute the slide of a potentiometer and if a very low auxiliary voltage could be provided to produce the desired output. The problem would then be resolved into constructing a potentiometer in which slide friction is negligible, bearing in mind the very slight torque of the millivoltmeter. Obviously, no suitable coil-type or carbon potentiometer exists.



On the other hand, if the pointer of the millivoltmeter moves in a fluid medium, friction can be considered negligible. Such a system, in which the signal applied to the moving coil (C) produces a deviation α, is shown above. A constant auxiliary voltage (2 or 4V) makes it possible, *via* electrodes (E) and (E'), to establish a suitable potential gradient in the fluid medium and to operate the recorder (P). Between the pointer and electrode (E), for example, it is possible to obtain a useful voltage which is a function of the deviation α, i.e., in this case, of the millivolts applied to (C). The trough can easily be constructed of perspex.

The stability of this system can be surprisingly high, provided precautions are observed regarding the choice of electrolyte, the type and size of the electrodes (E) and (E'), and the shape of the trough. In this connection, the use of a trough offers many possibilities for helping to eliminate distortion. This may be effected by varying the trough shape or, among other alternatives, by providing several intermediate electrodes in the same trough.

ELECTRONICS

A Pulsed-Curve Tracer for Semiconductor Testing.

By J. I. PANKOVE. (From *Electronics, U.S.A.*, Vol. 27, No. 9, September 1954, pp. 172-173, 4 illustrations.)

SEMICONDUCTOR devices exhibit a pronounced thermal sensitivity which often limits their usefulness. Even when the ambient temperature is constant, characteristics are affected by the power dissipated within the device. In *p-n* junctions the reverse impedance decreases with increasing voltage. Similar effects have been predicted and observed in the case of point-contact rectifiers. In tracing the voltage-current characteristic across a junction, the current is measured while a known varying voltage is applied. The resulting *V-I* curve is displayed on an oscilloscope. Thermal effects can be greatly reduced if the voltage is applied for a short time, during which the measurements are made.

The equipment described in this article gives an 80-μsec pulse every 4·4 milliseconds. Pulses increase linearly with time over a range of 0 to 350V. A d.c. bias of 0 to 100V may be added serially to the pulses, thus permitting investigations up to 450V. These excursions are repeated every 144 milliseconds. The circuit comprises a pulse generator and a saw-tooth generator, feeding their outputs into a gate, which comprises two cathode followers with a common cathode load. The output of the gate is a recurring sequence of increasing pulses, which are amplified in the final stage. The short pulses are generated by a one-shot multivibrator of the positive-grid-return type.

This pulsed-voltage sweep technique for determining *V-I* characteristics in semiconductors decreases thermal effects on measurements. By making comparisons with curves taken with non-pulsed supply, causes of rectifier breakdown can be ascertained.

FOUNDRY PRACTICE

Plaster Casting of Light Metals.

By G. R. GARDNER. (From *Product Engineering, U.S.A.*, Vol. 25, No. 9, September 1954, pp. 164-168, 7 illustrations.)

THE range of parts which can be cast from aluminium has been extended to many new applications by the development and perfection of a new foundry process based on plaster as the mould material. This plaster technique makes possible the casting of sections $\frac{1}{16}$ to $\frac{1}{8}$ in. in thickness, with a surface finish of 125 micro-inches r.m.s. or better. In addition, dimensional tolerances closer than those accociated with sand and permanent mould methods can be achieved.

A typical application in which these design features are capitalised is in bladed parts, such as automotive torque-converter castings, where plaster cores are used to maintain blade tolerances and surface smoothness. Similarly, advantages are also to be gained in the large-scale production of small parts where fine detail, smooth surface, close dimensional tolerance, and freedom from flash are important. These benefits are obtainable in plaster without the large die or tool expense associated with die casting.

One of the most interesting design possibilities offered by the new plaster process centres around the use of composite moulds. For example, three mould

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materials can be used to produce a single casting—plaster, where smooth surfaces and close tolerances are important; iron and/or sand elsewhere. The designer can thus achieve a nearly optimum surface condition, strength, and tolerances at low cost.

Although a number of plaster processes have been used in foundries, this particular technique is characterised by the high permeability of the plaster. This property is attributable to millions of tiny, interconnected pores or air spaces which promote the escape of gases generated when molten metal is poured into the mould. When ready for pouring, plaster moulds have a relatively low density and a highly porous structure consistent with their high permeability values. As a result of its cellular structure, the plaster mould material is also a good heat insulator. This characteristic permits the pouring of much thinner sections than is possible in the more conventional sand or iron moulds, which have a greater chilling effect.

ILLUMINATING ENGINEERING

Reflection Properties of Dry and Wet Road Surfaces.

By J. B. DE BOER and A. OOSTRIJCK. (From *Philips Research Reports, Holland*, Vol. 9, No. 3, June, 1954, pp. 209-pp. 224, 14 illustrations.)

DURING the past twenty years, much work has been devoted to the study of the reflection properties of road surfaces. However, for the purpose of road lighting, the results published up to now have been either incomplete or insufficiently accurate, while methods and equipment which have been applied for the measurement of the reflection properties of road surfaces have been rather complicated; furthermore, a rapid predetermination of road luminance could be made for only one road surface in dry condition. This paper provides further material in this respect by showing the reflection properties of four road surfaces, all of them in the dry, as well as in the wet, condition.

The very simple means used by the authors for making measurements in the laboratory and in the field are also described. Quantitative data are given on the reflection properties of a number of road surfaces common in the Netherlands. These data have been given for those directions of light incidence and observation which are of importance in lighting practice, and have been presented in a special diagram, in order to enable engineers to make calculations on the luminance of road surfaces quickly and simply.

IRON AND STEEL

Elimination of "Stretcher Strains" in Mild-Steel Pressings.

By B. B. HUNDY. (From *Journal of the Iron and Steel Institute, London*, Vol. 178, Part 2, pp. 127-138, 22 illustrations.)

THE terms "stretcher strains" or "Lüders lines" are used to describe the flamboyant markings which sometimes appear on the surface of steel pressings during a light draw. These markings are caused by plastic yielding of some portions of the steel, while other parts are strained only elastically. The formation of this defect is intimately connected with the discontinuous yield point of mild steel and, if this yield point can be removed, the steel will not form stretcher strains in pressings.

In this paper, it is shown that temper-rolled mild-steel sheet contains high residual stresses; these stresses mask the yield-point elongation of the steel and enable it to be pressed after appreciable ageing, without showing stretcher-strain markings. Other methods of eliminating stretcher straining, such as roller levelling or stretching the sheet through the yield-point elongation, do not induce such high stresses, and such sheet must not be permitted to age for more than a few hours, if this defect is to be avoided. Both macroscopic and microscopic residual stresses can mask the yield-point elongation and, in general, it is best to process the sheet so as to give high stresses of both types. Only stretcher strains are marked by residual stresses, the changes in ductility, hardness, and strength during strain ageing being unaffected by the method of removal of the yield point.

Temper-rolled sheet is usually flattened in a roller leveller after rolling, and it is shown that, if such levelling is carried out with the minimum intermesh of the rollers, the time for which each sheet can be stored without stretcher strains occurring on pressing is reduced. Roller levelling, with the maximum intermesh, however, is not as detrimental as light levelling and, if the temper-rolling reduction is light, may even be beneficial.

MACHINE-SHOP PRACTICE

Helical Carbide Milling Cutters.

(From *Steel, U.S.A.*, Vol. 135, No. 7, August 16, 1954, p. 115, 3 illustrations.)

UNDER proper machine conditions, cutting speeds have been tripled by the use of helical carbide milling cutters. Furthermore, chips are freely expelled by these cutters from the cut and do not cling to the cutting teeth. Elimination of this factor alone is responsible for a drastic reduction in tool breakdowns. Another important factor is that of greatly reduced vibration. Machine vibration was found to be less with these cutters than that produced by slabbing cuts on hardened steel with other types of carbide cutters.

The cutters used in tests and production work are helical end mills, 3 in. in diameter, with six blades, 3 in. in length. Helix angle is 15 deg., and the shanks are 2 in. in diameter. As an example of the capabilities of these cutters, the turned, 10-in. diameter ends of hardened steel forgings, quenched and drawn to 270 Brinell, for drive shafts of steel mills, were rough-milled to produce tongues of $3\frac{1}{2}$ in. in thickness by $4\frac{3}{8}$ in. in length. The average rate of stock removal was 2·1 lb per minute for a total of 100 lb removed. Spindle speed was 400 rpm, with a cutting speed of 314 sfm and a feed of 10·5 ipm. The chip load was 0·0044 in. per blade. Time was reduced from 145 to 49 min.

The greatest field of application for these cutters appears to be for steels, particularly those which are heat-treated to tensile strengths of more than 200,000 psi. Finishes of 30 micro-inches r.m.s. and better have been reported on high-alloy steels with tensile strengths approximating 200,000 psi. In tests on non-ferrous metals, removals of 6 to 8 cu in. per minute per horsepower have been reported.

Helix angle for these materials and for soft steels is 50 to 100% greater than for hardened steels. The rake angle for steels is zero. Clearance angles and lands vary with the properties of the material to be cut.

MATERIALS TESTING

The Practical Testing of the Cohesive Strength and Weldability of Steels.

By W. A. FELIX. (From *Sulzer Technical Review, Switzerland*, No. 1, 1954, pp. 33-43, 13 illustrations.)

THE testing of materials with a view to a specific application always raises the problem of the best testing methods, or more explicitly the testing methods yielding the clearest information about the properties upon which practical serviceability depends. While it is very rare that a material can be tested under the conditions to which it will actually be subjected in service, the endeavour must obviously be made to find test conditions reproducing the practical requirements as nearly as possible. This has led to the development of numerous procedures designed to test specific properties and to take account, as far as possible, of actual working conditions.

Regarded from this angle, the tensile test is usually only loosely connected with the stresses to be expected

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in service. Cases in which structural materials are subjected to homogeneous and purely uni-axial tension are no doubt rare. This does not mean, of course, that the tensile test has no justification. It is often known from experience that a component must have certain strength properties which can be determined in the tensile test. The properties revealed by this test also permit materials to be generally classified and designated.

The suitability of a steel for use in highly stressed welded structures depends on a number of properties which it is not easy to determine in the laboratory. Apart from the yield point and the tensile strength—the figures on which the designer bases his calculations—weldability and the capacity of the steel for deformation under multi-axial stress are both particularly important factors. The main criteria of suitability for a given application are detailed in this article, together with the best known testing techniques and the methods adopted by Sulzer Brothers for assessing the properties of such steels. In conclusion, the results of a few practical investigations are cited.

STRESS ANALYSIS

The Elastic-Plastic Theory of Containers and Liners for Extrusion Presses.

By M. R. HORNE. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, September 1954, 12 pages, 19 illustrations.)

IN the extrusion of metals, the container in which the charge is confined during extrusion is subjected to high internal pressure at an elevated temperature. The usual practice is to fit the container with a liner of different material. In order to withstand the high radial pressure exerted by the charge, the external diameter of the container is usually several times the internal diameter of the liner but, even in those circumstances, it is found that the diameters of the liner and the internal diameter of the container increase slightly in use. It is therefore certain that some plastic deformation of both liner and container must take place. The range of pressures over which the assembly can behave elastically may be increased by shrinking the container over the liner, but even this does not appear to prevent some increase in the internal diameter of the liner. Fortunately, small increases in diameter do not usually cause trouble, since the inside of the liner itself becomes lined with a layer of the metal being extruded. It is thus admissible to make use of plastic behaviour in the design of containers and liners. This paper is concerned with the theoretical aspects of such an approach.

Several theories dealing with the behaviour of thick tubes in the partially, and fully, plastic states have been given. These theories differ in the assumptions regarding the yield conditions and also in the stress-strain relations assumed in the plastic range. Most of the theories are only approximate, and they commonly neglect the requirements of strain compatibility at elastic-plastic boundaries.

In this paper, reasons are given for basing the design of containers and liners for extrusion presses on elastic-plastic behaviour. After a review of the available theories on the behaviour of thick tubes and rings beyond the yield point, a solution based on the stress-difference theory of elastic breakdown is adopted. The application of this solution to containers both with and without liners is elaborated, and expressions are derived for the internal pressures sufficient to cause initial yield and full plasticity. Consideration is given to the possible occurrence of alternating yield on the inner surface of either the liner or the container. It is also found that, in certain circumstances, a tapered liner will progressively penetrate the container against the taper at pressures less than those required to produce complete plasticity.

The results of the analysis are presented in the form of charts, which cover the whole range of practical conditions.

WAVE MECHANICS

The Attenuation and Reflection of Compression Waves Propagated in Pipes.

By G. F. MUCKLOW and A. J. WILSON. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, September 1954, 12 pages, 18 illustrations.)

THE investigation described in this paper supplements a previous examination (Bannister and Mucklow, 1948) of the wave action following the sudden discharge of compressed gas into pipes. The paper consists of two parts :—Part I deals with the relation between the

MEASUREMENT OF HYDRODYNAMIC PRESSURE ON SHIP MODELS

(*Concluded from page* 439)

the aid of a calibration chamber specially designed for preliminary measurements, in which the cell is inserted at the bottom of a cylindrical chamber, which is then filled with water (Fig. 3). An eccentric, driven by an electric motor, varies the volume of air in the upper part of the calibration chamber by deflecting a flexible bellows arrangement, and pressure pulsations are generated in this manner. The frequency is varied by altering motor speed. The tests thus determined the frequency characteristic of the pressure cell. The curves obtained showed an absolutely flat response within the measuring range of the recorder, i.e., from zero to 80 cps, without any noticeable resonance peak. The resonant frequency of the pick-up diaphragm and coil in air was measured as 455 cps. In water, it is considerably lower, but was not indicated in the tests.

PRESSURE MEASUREMENTS ON A MODEL HULL

The pressure cell was tested on a self-propelled ship model (length 5·2 m, speed 1·85 m/sec). The cell was inserted at the rear of the hull, in the neighbourhood of the propeller, with its diaphragm flush with the counter.

Tests were carried out with the model driven by a three-bladed propeller, subsequently replaced by a four-bladed propeller. The results clearly showed that the four-bladed propeller causes lower pressure fluctuations than the three-bladed propeller (with amplitudes three times less in the tests considered). Further details are given in the table below.

Number of propeller blades	Propeller speed rps	Pressure frequency cps	Ratio of dynamic to static pressure %
3	14·0	42·4	10·0
4	9·8	40·0	3·5

In order to investigate whether hull vibrations were affected by the pressure cell, a vibration pick-up was mounted on the hull in the immediate vicinity of the cell. The tests indicated that the vibrations were not transmitted to the pressure cell through the hull but only through the direct action of the water. The pressure cell has been tested for a considerable period and has proved its reliability in operation.

Regarding the type of diaphragm used, it may be noted that it can be operated at pressures up to several metres of water, and therefore it should also be completely suitable for full-scale tests on ships.

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(1) TUCKER, M. J. : A linear transducer for the electrical measurement of displacement. *Electronic Engineering*, Sept. 1952, p. 420.

(2) PFEIFFER, A. : A note on the theory of corrugated diaphragms for pressure-measuring instruments. *Rev. Sci. Instruments*, Vol. 18, No. 9, Sept. 1947, p. 661, Table I.

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frictional attenuation of compression waves propagated in pipes and the effects of friction under conditions of steady flow. The object of the work covered in Part II was to compare experimentally the pressure amplitude of compression waves before and after closed-end and open-end reflection, with a view to verifying considerations based on theoretical argument.

The apparatus consisted of a series of cylinders with bores of 1·5, 2·0, and 4·285 in., from which compressed air was discharged suddenly into pipes of varying lengths and of the same bore as the cylinder in use. Indicator diagrams were recorded at suitable intervals along the pipes.

Theoretical considerations show that, with the same particle velocity, a simple relation exists between the rate of decay of small-amplitude waves and the steady-flow pressure drop along a pipe. Experiment suggests that this relation applies approximately to finite-amplitude waves and, on this basis, a simple expression is devised to relate wave-head decay with initial amplitude, pipe diameter, and distance propagated, within the range considered. By use of this expression, the mean velocity of propagation may also be determined.

The processes of open- and closed-end reflection of compression waves are examined and considerations outlined in an appendix to the previous paper are amplified. The resulting conclusions are supported by experimental evidence. The effects of discharge through a constriction are considered in an appendix.

WELDING

The Use of Slope Control in Spot Welding Thin Aluminium.

By I. W. JOHNSON. (From *The Welding Journal, U.S.A.*, Vol. 33, No. 8, August 1954, pp. 759-762, 4 illustrations.)

THE effect of slope control in spot-welding aluminium alloys, with emphasis on thicknesses of $\frac{1}{16}$ in. and more, has already been reported. Spot welding of thin sheets of aluminium alloys, ranging in thickness from 0·016 to 0·040 in., has presented problems which have been difficult to overcome with standard single-phase equipment. Stored-energy machines have been satisfactory, and for that reason many manufacturers have retained such equipment for the sole purpose of welding thin aluminium-alloy sheets. It was considered, therefore, that if a.c. power could simulate the characteristics of stored-energy discharge, standard single-phase equipment would become satisfactory.

Up-down slope control provides a means of simulating the wave shape of stored-energy discharge. The electronic voltage regulator provides the means of maintaining the magnitude of the current just as precisely as the stored-energy equipment. Single-phase spot welders equipped with these two controls are capable of spot welding thin sheets of aluminium satisfactorily.

This paper presents data pertinent to the use of up-down slope control with electronic voltage regulation on single-phase a.c. welding equipment. A summary of these data shows that satisfactory spot welds can be obtained on single-phase equipment; that crack-free welds can be made in 24ST aluminium without forging pressure; that lower electrode force can be used, resulting in a substantial reduction in current demand; and that tensile shear strengths show phenomenal consistency.

ERRATUM

We regret that, in the Classified Abstract on page 338 of our issue for August, 1954, the name of Professor J. A. Pope, as co-author with Dr. D. G. Wilson of the paper on "Convective Heat Transfer to Gas-Turbine Blade Surfaces," was inadvertently omitted.

SELECTION OF APPRENTICES IN THE ENGINEERING INDUSTRY

(*Concluded from page* 418)

been using the procedure for more than seven years, and in any one of them the number who have completed training is still too small for a full-scale statistical analysis at this stage.

Some analysis has, however, been made and, while the evidence so far available cannot be regarded as conclusive, it strongly suggests that the tests do provide a dependable indication of the abilities they are designed to measure. For example, the battery of tests was administered to a group of engineering apprentices and a group of trade apprentices in the same firm. The engineering apprentices were considerably better than the trade apprentices and the above-average trade apprentice better than the below-average engineering apprentice, in most of the tests, indicating that the tests can differentiate between the good and the not so good. Since a passed City and Guilds is more satisfactory to both the apprentice and his firm than a failed National Certificate, it would appear that the procedure can be of considerable value in deciding appropriate courses of technical study, particularly when it is borne in mind that many firms tend to be unduly ambitious for their boys.

The general level of success in technical colleges is believed to be higher for firms using the procedure than for the country as a whole. As many as 80% of student apprentices in some firms are reaching National Certificate level and a substantial proportion of them go on to take their Higher National Certificate. Trade apprentices selected by the test procedures are also found, as a rule, to achieve a higher standard of success in technical colleges. One or two firms using the procedure have gone so far as to state that they no longer have any failures.

The procedure is generally regarded as demonstrably fair by managers, sponsors of applicants, and also by the applicants themselves, who appear to enjoy the tests. In fact, it has been found that the introduction of systematic selection procedures tends to attract an increasing number of applicants for apprenticeship, thus enabling standards to be raised still further. Training officers and others responsible for the training of apprentices have expressed their satisfaction with the results obtained and most firms who have given the tests a trial are still using them.

The National Institute of Industrial Psychology has assisted firms in two ways. On behalf of small firms, its investigators have tested, interviewed, and reported on the suitability of candidates, but in larger firms, where there are greater numbers of apprentices and where training officers or apprentice supervisors are available, it is usually considered preferable that they should carry out this work themselves. Instruction is then given, not only in methods of scoring and in the interpretation of results, but also in the procedure for interviewing and in the method of relating information obtained from the various sources.

Advice is also given on establishing an efficient procedure for following and recording the progress of candidates selected by this system. In this way, firms are to some extent provided with a measuring instrument which they are able to calibrate themselves by their own follow-up procedure. They are thus in a position to vary acceptance standards from time to time, in accordance with the quality of available candidates and with their own requirements.

It is also possible that, by watching results closely for a number of years, individual firms may be able to set standards, if not for particular trades, at any rate for groups of trades making similar demands.

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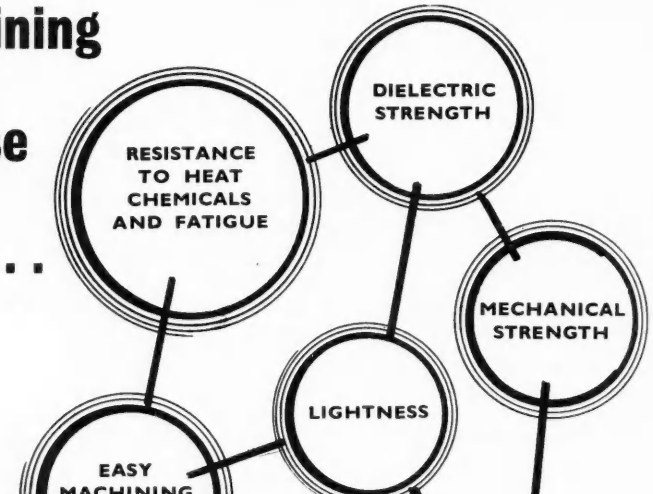

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NEWS OF THE MONTH

PERSONAL

Mr. D. G. W. Acworth, M.A., M.I.E.E., manager of the Export Department of The General Electric Co. Ltd., Magnet House, Kingsway London, W.C.2, and a director of the Anglo-Argentine General Electric Co. Ltd., has been appointed a director of the Overseas Companies of the G.E.C. in Australia, New Zealand, South Africa, Central Africa, India, Pakistan, Burma, Malaya, Hong Kong and Canada.

Mr. G. H. Asbridge, chief designer of Sentinel (Shrewsbury) Ltd., has been appointed Head of the Machine Tool Division and has been elected to the Board of the Company.

Sir George E. Bailey, C.B.E., M.I.Mech.E., M.I.E.E., chairman, and **Sir Felix J. C. Pole,** deputy chairman, of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17, have resigned from the Board of Directors. **The Rt. Hon. The Viscount Chandos (formerly Mr. Oliver Lyttelton), P.C., D.S.O., M.C.,** has been elected a director and Chairman of the Board.

Dr. C. S. Ball has been appointed assistant chief metallurgist of the Steel Company of Wales Ltd.

Mr. W. J. Bird has been appointed, in addition to his present responsibilities as sales manager for the London and Southern England area, deputy sales manager of The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.

Mr. L. L. Bott, M.I.Prod.E., general works manager, and **Mr. A. G. Howe, M.B.E., J.P.,** chief engineer of Davey, Paxman & Co. Ltd., and **Mr. T. L. Kendall,** sales director of Ruston & Hornsby Ltd., Lincoln, have been elected to the Board of Davey, Paxman & Co. Ltd., Colchester.

Mr. Leonard M. Brodoway has been appointed managing director of C. C. Wakefield & Co. Ltd., 46 Grosvenor Street, London, W.1, in succession to **Mr. Alonzo Limb,** who has had to relinquish this office owing to ill health. Mr. Broadway joined the Company 34 years ago. He has been a member of the Board since 1947 and joint assistant managing director since 1952. **Mr. William F. List** has been appointed assistant managing director.

Rear-Admiral (E) W. G. Cowland, C.B., R.N.(Retd.), has been appointed deputy chief engineer, Turbo Charger Department (Gas Turbine Division) of D. Napier & Son Ltd., Acton, London, W.3. **Mr. A. J. Penn** is chief engineer of the Division. **Mr. J. C. L. Southam,** chief sales engineer, will be responsible for all turbo charger sales, and **Mr. Clifton Clark,** service manager, for all servicing.

Sir Harold Roxbee Cox, B.Sc., Ph.D., D.I.C., M.I.Mech.E. F.R.Ae.S., F.Inst.F., until recently chief scientist at the Ministry of Fuel and Power, has been elected a director of The Brush Group Ltd.

Mr. B. H. Douthwaite, A.M.I.E.E., has been appointed sales manager of British Physical Laboratories Ltd., Houseboat Works, Radlett, Herts. He will be responsible for the home sales of both British Physical Laboratories and the Quadrant Meter Company.

Mr. C. H. Foulkes, M.I.E.E., has been appointed Head of the Valve Division and location manager of the Standard Telephones & Cables Ltd., Dowlish Ford Mills, Ilminster, Somerset. He will be responsible for the development and manufacture of all special valves, with the exception of broadcast receiver valves.

Mr. Ronald M. Garland has been appointed a director of Veeder-Root Ltd., Kilspindie Road, Dundee, Scotland. He will continue in his position as deputy to the managing director and will be responsible for product development and manufacture.

Mr. J. Gilson, A.M.I.Mech.E., A.M.I.Prod.E., F.Inst.P.I., who has recently relinquished his position as chief production development engineer with Hoover Ltd., having completed 20 years' service with the Company, is to establish professional practice as consultant-inventor at 106 Westbury Road, New Malden, Surrey.

Mr. A. G. Grant, M.Sc., M.I.Chem.E., M.Inst.Gas.E., director and general manager of Whessoe Ltd., Darlington, has been appointed managing director of the Company, in succession to **Mr. C. M. Spielman, O.B.E., M.C., M.I.C.E., M.I.Struct.E.,** who has relinquished that position, but is retaining his seat on the Board.

Mr. W. G. Ibberson has been elected to be the 319th Master of the Cutlers' Company in Hallamshire for 1954-55, in succession to **Mr. R. L. Walsh. Mr. R. P. Phillips** has been elected Senior Warden and **Mr. P. G. Robets, M.P.,** Junior Warden.

Mr. John Johnston has been appointed general manager, and **Mr. Donald N. Wilcockson,** production manager, of the Hydraulic Department of Stein & Atkinson Ltd., 60 Buckingham Palace Road, London, S.W.1.

Mr. R. R. Kenderdine, M.I.Prod.E., has been appointed an executive director of Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2. He will be responsible for the Company's works both at home and overseas, with the exception of the Guisley and Doncaster works concerned with the production of lamps, tubes and lighting fittings. These works will remain the responsibility of **Mr. R. E. P. Briebach** who has recently been appointed to the Board of F. & A. Parkinson Ltd., Guisley.

Mr. J. Lawrence, until recently assistant district manager for the North-West area at the Manchester branch of G.E.C., has been appointed manager of the Instrument and Switchgear Department of The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2, in succession to **Mr. F. R. Unwin, M.I.E.E.,** who has now retired. **Mr. E. G. Taylor, B.Sc.(Eng.), M.I.E.E.,** has been appointed assistant district manager for the North-West area.

Mr. J. G. McLeod has been appointed works manager of the Willesden factory of Bowden (Engineers) Ltd., Victoria Road, Willesden Junction, London, N.W.10.

Mr. J. W. C. Milligan has relinquished his position as managing director of Brush Electrical Engineering Co. Ltd., Loughborough, a subsidiary company of The Brush Group. As from the 28th September, 1954, **Mr. M. Tattersfield,** formerly deputy to Mr. Milligan, has assumed responsibility for the mangement of Brush Electrical Engineering Co. Ltd., as director and general manager.

Mr. D. H. Smith, B.Sc.(Eng.), A.M.I.E.E., has joined Brush Electrical Engineering Co. Ltd., Loughborough (a member of The Brush Group), as chief engineer of the Transformer Division.

Mr. C. G. Tangye, M.I.Mech.E., has been elected Chairman of the Council of the British Internal Combustion Engine Research Association, Buckingham Avenue, Slough, in succession to **Mr. H. Norman Allen.**

Mr. R. R. Whyte, M.B.E., B.Sc.(Eng.), has assumed control of the Metropolitan-Vickers Electrical Co. Ltd.'s Germiston Works, Glasgow, manufacturing steam turbine condensers and associated auxiliaries. This appointment is in addition to his present responsibilities as superintendent of the Small Turbine Department at Trafford Park, Macnhester 17.

The Stand of "The Engineers' Digest" at the 4th European Machine Tool Exhibition, recently held in Milan, was favoured by a visit from Mr. E. J. Joint, C.M.G., O.B.E., H.M. Minister (Commercial) and Mr. J. S. Rooke, First Secretary (Commercial), British Embassy, Rome.

They showed great interest in "The Engineers' Digest" display, designed to promote the interests of its advertisers among the many buyers of industrial equipment attending the Exhibition from all over the world, and expressed their

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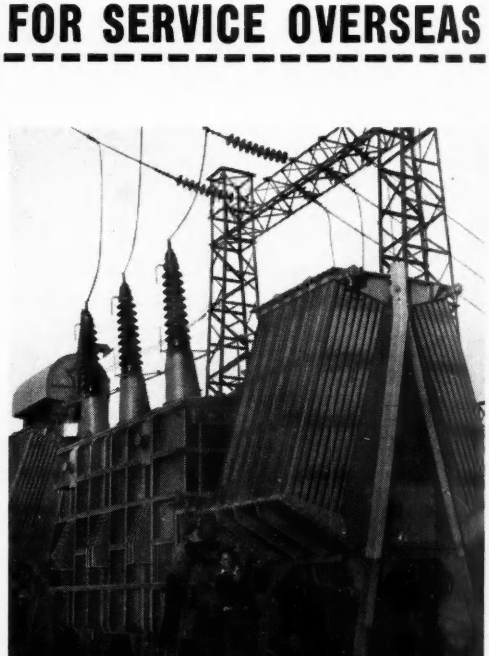

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appreciation of the value of such overseas publicity to British industry.

The Stand featured a large board on which the names of our advertisers were conspicuously displayed. On the two side-walls and on the main counter of the Stand leaflets, brochures, and technical data sheets of British industrial firms were displayed. Thousands of leaflets and brochures have been distributed to interested visitors of the Exhibition from all parts of the world.

BUSINESS NOTES

Dowty Auto Units Ltd. has changed the name of the Company to Dowty Hydraulic Units Ltd. The management and personnel of the Company remain unaltered, and the same address is retained at Ashchurch, Nr. Tewkesbury, Gloucestershire. Telephone: Tewkesbury 2271. The activities of the Company will continue to be concerned with the design and production of hydraulic components for industrial applications.

The Mond Nickel Co. Ltd., on behalf of its parent company, The International Nickel Co. of Canada Ltd., announce the sale by Mond of its wholly owned subsidiary company, Birlec Ltd., Birmingham, to Associated Electrical Industries Ltd. Birlec will operate as an individual company within the A.E.I. Group. Mr. George P. Tinker will continue as managing director and Mr. T. G. Tanner and Mr. J. H. Crossley as executive directors.

John Harris Tools Ltd., Warwick, have opened, for the convenience of Scottish customers, a sales and stock office at 74 York Street, Glasgow C.2. Tel.: Central 3187. A representative range of Harris Taps, Dies and Gauges will be carried, and trained staff is available for technical advice.

The Telegraph Construction & Maintenance Co. Ltd., Telcon Works, Greenwich, announce the opening of a new Branch Office and Depot at 2, St. Nicholas Buildings, Newcastle-on-Tyne 1, under the management of Mr. R. Fenwick. Stocks are carried of P.V.C. Wiring Cables and Flexibles, Radio Frequency and Broadcast Relay types of cables. The branch also handles enquiries for other Telcon products, including Paper Insulated Mains Cables, having copper or aluminium conductors and with either lead or aluminium sheathing, and products of Telcon's Plastics Division.

The Company also announce the opening of a London Sales Office at Norfolk House, St. James's Square, S.W.1, under the management of Mr. A. W. Matkin.

T. M. Birkett & Sons Ltd. and Billington and Newton Ltd., two long-established Stoke-on-Trent non-ferrous foundries, have amalgamated. The company will be known as T. M. Birkett, Billington & Newton Ltd., and will be one of the largest non-ferrous founding firms in the country. The Board of Directors remains unchanged: A. P. Wright (managing director), J. C. M. Sheckell, A. Birkett, E. Y. Birkett and F. Bennet. Headquarters of the company will be a newly-erected administrative block at Hanley which includes spacious office accommodation, drawing offices and a laboratory.

The foundries and machine shops at both Hanley and Longport will remain in operation and each will continue to offer a personal service to its own customers as in the past.

Thos. W. Ward Ltd., of Sheffield, announce that they have purchased the entire share capital of Fredk. Town & Sons Ltd., of Halifax, machine tool manufacturers, specialising in the manufacture of radial drilling machines. **Mr. Harold Vernon** and **Mr. G. Stuart Wood** (directors of Thos. W. Ward Ltd.) have been appointed to the Board and **Mr. Harold Vernon** has been appointed Chairman and Managing Director. **Mr. Eric Town** who has been with the company for 25 years, remains as a director and general manager of the company.

Dowding & Mills Ltd., Birmingham, announce that owing to the expansion of their London business, it has been found necessary to effect a re-organisation. **Mr. Peter Hollings** will take over duties as London Manager at the works at 24 White Post Lane, Hackney, E.9. **Mr. W. G. Smith** has been appointed technical manager of the London works. **Mr. W. L. Henderson, A.M.I.E.E., M.A.S.E.E.,** retains the responsibilities of London sales manager.

Epoxide Resins Patent Agreement. An agreement has been reached between Aero Research Limited and Shell Chemicals Limited covering, in the United Kingdom, the patents held by Ciba and Shell in the field of epoxide resins.

This agreement will be of particular value to the paint industry in that it will give freedom under both the Ciba and Shell patents to all purchasers of epoxide resins from either Company to sell or use these materials in the surface coating field.

In the specialised fields of potting, casting, laminating and adhesives, similar freedom under the patents will be available to customers purchasing epoxide resins from either Company for their own use but not for resale in their original or modified form.

Chamberlain Industries Ltd., Staffa Works, London, E.10, have recently appointed Drummond Asquith (Sales Ltd., King Edward House, New Street, Birmingham 2, as sole distributors in the United Kingdom of the production tube bending machinery which they design and manufacture in conjunction with Walter P. Hill Inc. of Detroit, Michigan, U.S.A.

The continued growth in membership of the **Institution of Engineering Designers** has made it possible to establish its own headquarters at 38, Portland Place, London, W.1. Telephone: LANgham 8847.

Lord Nuffield is the President and H.R.H. the Duke of Edinburgh recently associated himself with the Institution by becoming an Honorary Member.

Hoover Limited has established an associated company in New Zealand. It is Hoover Sales and Service Limited, 105/107 Anzac Avenue, Auckland.

The newly appointed managing director is Mr. F. W. Cave, himself a New Zealander, who has represented Hoover Limited in New Zealand for many years.

The premises at Anzac Avenue consist of offices, showrooms, workshop and stores.

ENGLISH STEEL CORPORATION'S NEW FILM

When we received an invitation to the recent preview of the English Steel Corporation's new 50-minute colour film, "Engineers in Steel," we must confess that we accepted with a faint cynicism, particularly when we were informed that it was produced by the Corporation's own Film Unit in co-operation with their Publicity Department. Frankly, we have seen a great number of so-called publicity films, some good, some only fair, and some execrably bad. Indeed, our experience has been that, as a general rule, Publicity Departments and conscientious and expert Film Units seldom mix well, principally because the insistence on plain, unvarnished advertising of the former is so often incompatible with any artistic inclinations of the latter.

Here, at last, is a glorious exception. Publicity Department and Film Unit have combined to produce a film of outstanding merit by any standard. Smoothly and artistically the film traces the history of the Corporation in a beautifully conceived and executed series of shots, blending harmoniously and imperceptibly into details of their vast range of present-day activities, including dramatic sequences of melting processes, the rolling of heavy mild-steel plate, the making of giant castings and forgings, and the various stages in the manufacture of crankshafts, wheels, turbine discs, springs, and small tools.

Apart, however, from the absorbing interest of the activities it covers, it is in production and presentation that the film achieves true excellence. The photography is suberb and at times of the highest artistic merit. Script, editing, and direction are of superlative standard. The commentary (by Frank Phillips), though comprehensive, is admirably spoken and is never obtrusive, while the quality and dramatic value of the background music (specially composed by Dr. George Linstead and played by the Yorkshire Symphony Orchestra) is well recorded, bearing in mind the range limitations imposed by 16-mm film.

We understand that, in addition to English, five foreign-language versions are being produced. This is an excellent idea, for, apart from the world-wide reputation enjoyed by the English Steel Corporation's productions in steel, this is yet another production of which they can well be proud.

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THE ALBRIGHT & WILSON LTD. SILICONE PLANT

Under the auspices of Midland Silicones Limited, of London, a visit was paid on October 6th to the Albright & Wilson Ltd. Silicone Plant, in Barry, near Cardiff, Glamorganshire. This is the first full-scale silicone plant in Great Britain, and this visit marks the first occasion on which any details have been made public or any member of the Press has seen the plant.

The plant, which is located on a site covering 26 acres, was designed by the company's own Central Engineering Department, and is based on full working drawings supplied by the Dow Corning Corporation, U.S.A., whose knowledge and experience in the field of silicone science and technology has always been freely available. As was amply demonstrated during a comprehensive tour of the plant, the processes employed are complex and need to be carried through many stages with the greatest care, in order to produce pure materials in good yield. Thus, for instance, the separation of chlorosilanes by fractionation is extremely difficult because their boiling points lie close together, necessitating the use of distillation columns of great efficiency.

The handling of the hazardous and highly reactive intermediate products and solvents used in silicone production also presents considerable difficulties. In all stages in the production of the chlorosilanes, including the distillation process, the entire system has to operate under anhydrous conditions; thus, the plant has had to be designed to ensure the complete exclusion of atmospheric moisture. Furthermore, elaborate safety and fire precautions are necessary. The volatile solvents and intermediate products of the process are stored in buried tanks, while the tanks and all parts of the system are purged with inert gas, to prevent ingress of air and to reduce the risk of fire. Protective clothing, including safety glasses and helmets, are worn by all personnel working in hazardous areas.

A wide range of products is produced, including silicone rubbers, water repellents, and release agents. Distribution and sales, both home and overseas, are in the hands of Midland Silicones Ltd., which is a subsidiary company owned jointly with the Dow Corning Corporation. Midland Silicones Ltd. was formed in 1950, Albright & Wilson Ltd. having undertaken distribution themselves since 1946.

NEW USES FOR POLYTETRAFLUOROETHYLENE (P.T.F.E.)

Polytetrafluoroethylene (P.T.F.E.) is a resin-like substance unique among organic compounds in its chemical inertness, its toughness over a very wide range of temperatures, its excellent insulating properties and its unusually low co-efficient of friction. It is of particular interest to the electrical, chemical and engineering industries and wherever the problem of handling sticky materials is encountered.

These same properties of chemical inertness and non-sticking have hitherto presented difficulties of fabrication which have in turn limited its application.

Now by newly developed processes The Edison Swan Electric Co. Ltd., are able to produce "P.T.F.E." bonded to metal or rubber, "P.T.F.E." bonded fibre-glass laminates, continuous length "P.T.F.E." cylinders and "P.T.F.E." beakers for laboratory use.

Metal-backed "P.T.F.E." will find a number of applications in the electrical industry. It can be readily fixed to any support by soldering or mechanical means and the adherence of the metal bond is such that satisfactory hermetic joints can be achieved.

"P.T.F.E." bonded with rubber combines the flexibility of rubber with the complete chemical inertness of "P.T.F.E." Laminates of this type make excellent valve and pump diaphragms, washers, seals and flexible couplings.

"P.T.F.E." bonded fibre-glass laminates have excellent electrical and mechanical properties which remain unimpaired at extremes of temperature. They are already being used as electrical insulators on Jet Aircraft and in other similarly arduous conditions.

Continuous cylinders of "P.T.F.E.", produced in a number of alternative diameters and lengths, are of interest to users of food processing and similar machinery for covering rollers handling sticky materials.

Due to its thermal properties and almost complete chemical inertness "P.T.F.E." is a very satisfactory alternative to Platinum as a material for beakers for laboratory use, and they show a considerable saving in cost.

CONFERENCE ON PLASTIC TOOLING

A special conference on plastic tooling organized by the Sheet and Strip Metal Users Technical Association, 49 Wellington Street, Strand, London, W.C.2, was held on October 14 and 15 at The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London W.C.2. The following papers were presented:

Some Experiments in the Suitability of Plastics for Press Tool Manufacture, by Prof. J. V. Connolly (Royal College of Aeronautics), P. K. Digby (Bristol Aeroplane Co. Ltd.), and W. J. Paul (Fairey Aviation Co. Ltd.).

The Use of Plastic Press Tools for the Production of Motor Vehicle Panels, by W. B. Kidd (Autolifts and Engineering Co. Ltd.).

Some Practical Aspects of the Manufacture of Forms from Plastics, by S. Matthews (Briggs Motor Bodies Ltd.).

Modern Tools Made from Epoxy Resins, by Dr. K. Meyerhans (Ciba Ltd.).

Tooling with Phenolic Casting Resins for Sheet Metal Pressing, by Dr. F. L. Gilbert (Catalin Industrial Resins Ltd.).

Glass Fibre Reinforced Plastics for Press Tools, Jigs, and Patterns, by A. M. Dobson (Fibreglass Ltd.).

The Devolopment of Plastic Tools with Particular Reference to the Use of Polyester Resins, by J. T. Maddison (Bakelite Ltd.).

INTERNATIONAL MACHINE TOOL EXHIBITION, LONDON, 1956

The next International Machine Tool Exhibition to be organised by The Machine Tool Trades Association will be held in 1956 from June 15th to June 29th inclusive at Olympia, London.

It will be the major machine tool exhibition of the year as, following an understanding with the European Committee for the Co-operation of the Machine Tool Industries, no other international machine tool exhibition will be held in Europe during 1956.

This will prevent a repetition of the overlapping which occurred in 1952 when the London exhibition coincided with that held at Hanover.

The following, in addition to the permanent staff of the M.T.T.A., form the Committee responsible for organising the International Machine Tool Exhibition, London, 1956.

H. P. Potts (Chairman), B.S.A. Tools, Ltd., Robert W. Asquith, William Asquith, Ltd., T. Bolton, W. S. Crawford, Ltd., W. Core, Alfred Herbert, Ltd., J. Frye, Victoria Machine Tool Co. Ltd., H. J. D. Kearns, H. W. Kearns & Co. Ltd., J. G. Petter, Cincinnati Milling Machines Ltd., J. F. Phillips, Universal Grinding Wheel Co. Ltd., R. D. G. Ryder, Thomas Ryder & Son Ltd., J. G. Sagar, J. Sagar & Co. Ltd., J. C. Snow, Snow & Co. Ltd., and the Hon. Treasurer of the Machine Tool Trades Association.

MIDLANDS ELECTRONICS EXHIBITION

The Scientific Instrument Manufacturers' Association announce an exhibition of Electronic Aids to Production, Design, and Research, to be held in Birmingham from the 23rd-25th November at the Chamber of Commerce Hall. Admission is by ticket obtainable free on request from the Association at 20 Queen Anne Street, London, W.1, the Chamber of Commerce, 95 New Street, Birmingham 2, the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham 2, or City of Birmingham Information Department, 57 Corporation Street, Birmingham.

The exhibition theme, Electronics in Action, will be exemplified by a large number of working demonstrations showing the employment of electronics in a wide range of industrial applications, in public services, medicine, and education, and in varied spheres of research and development.

THE CHEMICAL AND PETROLEUM ENGINEERING EXHIBITION

Arrangements have now been completed to hold for the first time in the United Kingdom a joint exhibition of chemical plant and petroleum equipment. This exhibition will be known as The

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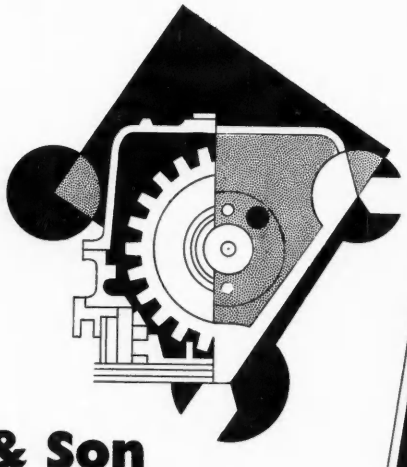

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Chemical and Petroleum Engineering Exhibition and will take place in the Grand Hall, Olympia, London, in June 1958; it will be organised by F. W. Bridges & Sons Ltd., and sponsored jointly by the British Chemical Plant Manufacturers Association and the Council of British Manufacturers of Petroleum Equipment.

ZINC ALLOY DIE CASTING EXHIBITION

The Zinc Alloy Die Casters Association is holding an Exhibition of zinc alloy pressure die castings at the Birmingham Exchange and Engineering Centre, Stephenson Place, in Birmingham from the 25th to the 30th October, 1954. It will be open each day from 9.0-5.0 p.m.

The Exhibition will consist of over 200 different zinc alloy die castings made in the United Kingdom, including one of the smallest castings produced, weighing approximately 1/100 oz.

Examples of the wide variety of finishes obtainable on zinc alloy die castings will also be shown.

The wide application afforded by this process will suggest to manufacturers possibilities of utilizing the zinc alloy die casting process for their products.

The exhibition coincides with the International Pressure Die Casting Conference being held at Church House, London, from October 25th to October 28th.

THE JUBILEE OF THE INVENTION OF THE THERMIONIC VALVE

In connection with the celebration of the Jubilee of the invention of the thermionic valve by Sir Ambrose Fleming on November 16th, 1904, a Conversazione will be held in the Electrical Engineering Department of University College London. A plaque commemorating the occasion will be unveiled by the Lord President of the Council.

In addition to exhibits and documents relating to Sir Ambrose Fleming's work while Professor of Electrical Engineering at the College, examples of recent researches will be on view. Admission to the Conversazione, which will extend over the three days November 16th, 17th and 18th, will be by invitation ticket only. A limited number of tickets for the 17th is available on application, and Senior Engineers or members of the Radio Industry who would like to visit the Exhibition at the College, which will be open from 3 p.m. to 10 p.m., should apply to the Assistant Secretary, University College, Gower Street, London, W.C.1.

ULTRASONIC MACHINING OF HARD MATERIALS

On October 19th, Mr. C. F. Brockelsby, B.Sc., A.R.C.S., A.M.I.E.E., of Mullard Research Laboratories, is giving a lecture on the application of ultrasonic techniques to the machining of hard materials to The London Graduate Section of the Institution of Production Engineers at their headquarters, 10 Chesterfield Street, London, W.1.

The lecture will commence with a brief survey of the historical background and principles of the ultrasonic method of machining. The present state of development of the technique and of the machines employing it will then be described and illustrated. The materials and operations to which it is applicable and the rate and accuracy of working will be fully discussed so as to bring out the unique advantages of the method.

Demonstrations using the Mullard 50 watt Ultrasonic Drill will be given.

ELECTROLYTIC COBALT PRODUCTION IN CANADA

As a result of improvements in refining techniques, The International Nickel Co. of Canada has initiated production of electrolytic cobalt at its Port Colborne refinery.

This marks the first commercial production of electrolytic cobalt in Canada.

Heretofore Inco's entire cobalt output has been marketed as oxides and salts produced at its Clydach, Wales, refinery. Through its new process the company makes available a high purity cobalt which will be particularly valuable in the manufacture of alloys where high purity is advantageous. Inco's electrolytic process for the production of cobalt was developed after extensive research and pilot plant studies by the company.

Cobalt is one of 13 elements recovered from the company's Sudbury District, Ontario, ores. Nickel, of course, is the principal product. The others are copper, platinum, palladium, ruthenium, iridium, rhodium, gold, silver, selenium and tellurium. In addition, Inco furnishes high quality smelter gas for conversion into liquid sulphur dioxide and normal smelter gas for sulphuric acid production. Soon, iron will be recovered as premium grade iron ore.

NEW TYPE OF CATIONIC AND NONIONIC CHEMICALS TO BE MADE IN UNITED KINGDOM

Armour & Co. Ltd., London, will sell next year from British production the range of chemicals now made solely by Armour & Company, Chicago. A new plant for producing these chemicals is being built at Littleborough near Rochdale, Lancashire, by Hess Products Ltd., and when completed the total plant will have cost in the neighbourhood of £250,000. Hess Products Ltd. have recently signed a contract with royalty payments to Armour & Company, Chicago, for which they have obtained the exclusive manufacturing rights and know-how for the new process and also any new developments in this field which might be discovered through the Armour research organization. Sales and distribution of the new chemicals, both for the home market and for export, are exclusively in the hands of Armour & Co. Ltd., Chemical Division, Lindsey Street, London, E.C.1.

This carries one step further the introduction into this country of a new line of chemicals pioneered and developed by Armour & Company in Chicago. It began here when Hess Products Limited started to produce the Distec range of fractionated fatty acids a few years ago. The new venture is a logical development of this. It will make available to British industry the vast experience gained by Armour & Company with this new line of chemicals.

THE NORTHERN FLEXIBLE CENTRE

To meet the heavy demands made on the "flexible" advisory service of Compoflex Co. Ltd., by industry in the Midlands and North of England, the company has opened a Northern Flexible Centre at their factory in Huddersfield Road, Oldham.

The centre, which was officially opened on Wednesday (6th October) by Mr. Ian Horobin, M.A. (Member of Parliament for Oldham East), is staffed by a team of specialists able to give advice on the most suitable flexible tube or hose to use in any given situation. A development section has also been started in Oldham, to deal with the design of special flexibles for particular projects.

FUTURE ATOMIC-POWERED AIRCRAFT

Now that nuclear power has become a reality for submarines, it is certain that before many years have elapsed aircraft will also be equipped with nuclear propulsion.

The first difficulty which is likely to arise is that of shielding the crew of the aircraft from the dangers of radio-activity. The weight of the metal shields which atomic-powered aircraft will have to carry will be great, and consequently the length of take-off and landing-runs will be much increased by comparison with those of today.

Moreover, it inevitably follows that the runways of the future will have to be able to bear vastly greater weights than those of today, which are already expensive to construct. The cost of building runways suitable for atomic-powered aircraft will be such that many countries may well choose to consider the use of the flying-boat as the starting point for their experiments in this direction.

It has been estimated by Saunders-Roe, the company which built the huge *Princess* flying boats, that for years to come the minimum all-up weight of an aircraft designed to use atomic propulsion will be in the region of 500,000 lb. It may well be still higher.

One of the advantages of the atomic power-plant is that its fuel consumption will be negligible for practical purposes. The corollary is obvious—that in future, landing weight will inevitably be a much higher proportion of take-off weight.

In order to give high performance, and keep the size of the aircraft within reasonable proportions, high wing-loading for take-off will have to be accepted. Wing-loading on landing will be much the same as at take-off, and a long landing-run will result. Saunders-Roe believe that this fact, coupled with the huge size of the aircraft, will put the landplane out of court.

The sea offers runways of unlimited length which are cheap, ready for use, and indestructible. Hence, the conclusion is that

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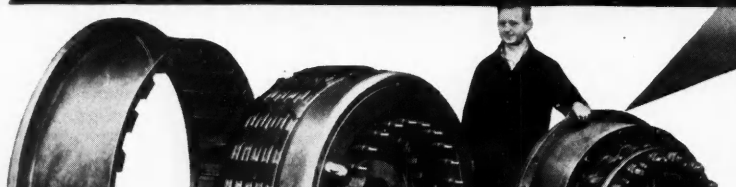

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The illustration shows a pneumatic Clutch-Brake assembly supplied for a 500 ton Forging Machine. Duty 1100 H.P. at 42 R.P.M., frequency 3-4 strokes per minute.

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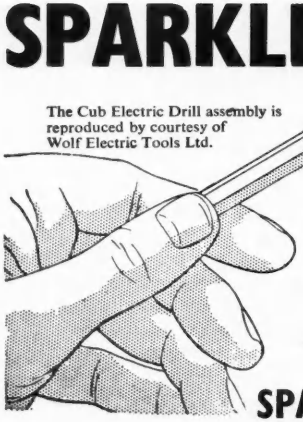

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the flying-boat is the natural medium for atomic propulsion. Behind the scenes, aerodynamic and hydro-dynamic research has been going forward which will enable Saunders-Roe to design flying-boats of the size required. In fact 60 per cent of this size has already been achieved in the shape of the *Princess* boats. This fact indicates that Britain will be as quick to take up the challenge of nuclear propulsion as she was to develop the gas-turbine engine.

NEW PATTERN MEDIUM DUTY TRUNKING

A medium duty metal-clad distribution system which, while having all the installation advantages of the heavy pattern has a lower amperage capacity, has been designed by The General Electric Co. Ltd. The busbar capacity ranges from 75 to 200 amp per bar. Equipment for the system consists essentially of two, three, or four hard drawn copper busbars totally enclosed in sheet steel trunking and supported at frequent intervals by high grade insulating panels. A visible and substantial external copper earth link is provided on the side of the trunking so that each length of trunking and all fittings can be electrically coupled and connected to give an efficient earth throughout the system. Spring contacts are provided at all outlet points to ensure that tap-off unit casings are earthed efficiently before contacts approach the live bars.

Conductors for the system comprise two, three, or four hard drawn high-conductivity copper bars in sections $\frac{3}{4}$ in. × $\frac{1}{4}$ in., for 75/100 ampere capacity, and $\frac{3}{4}$ in. × $\frac{1}{8}$ in. for 150/200 ampere capacity. Joints, which allow for expansion or contraction under varying temperatures, are at 12 ft. intervals and the bars are all supported at 3 ft. intervals by Bakelite insulators; additional supports being incorporated if fuse tap-off outlets are required at 2 ft. centres. The bars are also provided with a radiused edge on the bottom sections so that tap-off units can be fitted by an easy "plug-in" action. Each length of trunking is provided with outlets at 2 ft. or 3 ft. intervals to take these "plug-in" tap-off units. Insulating shield plates are fitted in the outlets to prevent accidental contact with the casing. Unused outlets are protected by removable steel sheet cover plates.

Trunking for the system is in 12 ft. sections of $9\frac{1}{8}$ in. × $2\frac{1}{2}$ in. 16 s.w.g. mild steel casing, treated with red-oxide primer as a rust preventative and finished in a glossy battleship grey enamel. It is fitted with overlapping sheet steel cover plates, secured by rust proofed screws, so arranged that they can be removed easily without removing the fuse units from the plug-in positions.

The 30 ampere tap-off units for use with the busbar system are supplied in a sheet steel case with a hinged door, spring catch and padlock plate. Supporting members, of $\frac{3}{8}$ in. diameter rustless steel are fitted with wing nuts and washers and each unit has robust contact fingers. The members are so arranged as to prevent the accidental reversal of phased sequence and form an integral part of the tap off unit, being threaded at the upper end for screwing into internally tapped sections within the trunking. This permits the securing of the tap-off unit to the system from the underside.

The contact fingers have either heavy copper contacts reinforced by steel springs to maintain high pressure contact with the bars, or contacts of a specially designed extrusion. A moulding is fitted within the tap-off to shroud the contact stems and is so designed as to permit the removal of unwanted contact fingers and the strapping of stems together as may be required. Strapping links are supplied as separate items.

Each tap-off unit contains the appropriate number of porcelain fuse bases and solid neutral link, and can be arranged for D.P., S.P. and N.T.P., or T.P. and N. systems as required.

NEW TRANSPORTERS AT BIDSTON DOCK

Two huge electrically operated transporters, each weighing 600 tons and of unique design, have recently been put into operation at Bidston Dock, Birkenhead.

Constructed by Joseph Booth & Bros., the transporters are to be used for unloading iron ore from ships at the dockside into waiting road, rail or barge transport for despatch to the Hawarden Bridge Steel Works, near Shotton, of John Summers & Sons Ltd. Each grab has a capacity of six tons and the time taken to pick up and discharge a grab-load is 60 seconds, giving each transporter a capacity of over 350 tons an hour.

The complete current collection equipment has been designed, manufactured and installed by British Insulated Callender's Cables Ltd. and its subsidiary British Insulated Callender's Construction Co. Ltd. in association with R. & J. H. Rea Ltd., Joseph Booth & Bros. and Wm. Cory & Sons Ltd.

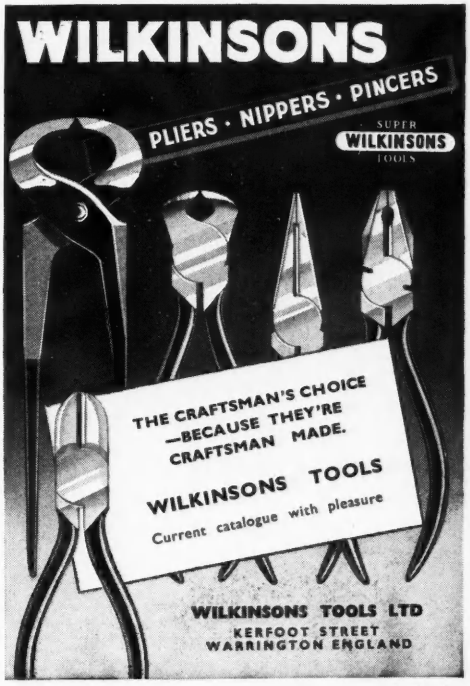
The 140-foot high transporters have a number of unique features. They are the only two in Great Britain which can unload either on to land or into barges, the length of the transverse boom—219 feet—allowing the grab to discharge into barges lying on the off-shore side of the ships.

The transporters themselves can move along the quay on rails for a distance of 1000 feet. The current collection equipment, for moving the transporters along their railway, is believed to be unique in Great Britain. An underground duct runs behind the transporters parallel with the rails, and the collectors of each transporter, together with the T-bars carrying the current, are therefore completely enclosed.

Installed in the duct are three 1000-foot copper T-bars, along which run the three current collectors fitted to each transporter. These are provided with 1000-ampere twin head carbon inserts and the T-bars are fixed to the side of the underground duct by means of steel brackets and insulated supports.

The current collection equipment for the cross-travelling cranes with their huge grabs presented special difficulties. The 219-foot booms along which the cranes move are hinged so that the 93-foot end section can be raised clear of the superstructure of ships to allow the whole transporter to move along from hold to hold and, as a result, special T-bar and trolley wire fittings had to be installed at the hinge. A three-phase and earth 440-volt system is used and each crane is provided with four main conductors in the form of $1\frac{1}{4}$" × $1\frac{1}{4}$" × $\frac{1}{4}$" copper T-bars as well as four control conductors of 1/0 S.W.G. grooved copper trolley wire. This necessitated 16 collectors being installed operating in parallel, two to a conductor. The collectors for the main conductors are of the heavy duty, porcelain insulated, spring type and all collectors are fitted with carbon inserts.

Working throughout the whole twenty-four hours, these giant transporters will help considerably to ensure a speedy turn-round of ships and a smooth flow of raw materials into the Shotton steelworks.



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BOOKS RECEIVED

Mechanics of Materials. Third Edition, 1954. By Philip Gustave Laurson, M.S., and William Junkin Cox, C.E. 422 pp., 491 illustrations. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall, Limited, 37 Essex Street, London, W.C.2. Price: 46/-.

Since it was first published over fifteen years ago, this book has won an established reputation, both as a reference and as a text. Professors Laurson and Cox examine the physical behaviour of stressed bodies, not merely from the viewpoint of mathematical expression, but also in the light of the practical problems confronting the engineer. They present their material in such a way that it is easily understood, and take particular care to express statements clearly and to support them with ample explanations.

This new edition retains much of the outlook of earlier editions. At the same time, however, it has been largely rewritten, with a view to adding to the book's clarity and timeliness. The most important changes are the increased emphasis on the statics of stress determination and the postponement of the material on stresses determined by deformation. The chapter on combined stress has been re-arranged to give increased emphasis to Mohr's Circle. Other changes include the revision of the tables of structural shapes, which have been brought into line with modern standards; the addition of a whole series of new problems, many of which are based on actual, well known engineering structures; and the addition of many new illustrations.

Lighting for Color and Form. By Rollo Gillespie Williams, F.I.E.S. 356 pp., 137 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 45/-.

This interesting and well presented book brings together a vast number of different but related branches of knowledge concerning lighting for the architect, the scientist, the engineer, the designer, the lighting technician, the artist, the display expert, the photographer, and the contractor.

For convenience, the book has been divided into four parts:—Part I deals with the scientific factors underlying the subjects covered in the book, including the latest information on additive colour blending. Part II discusses the important characteristics and details of light sources and filters which are useful in the field of applied colour and directional lighting, together with equipment suitable for colour, accent, and modelling work or for architectural, concealed, or colour lighting effects. Part III defines some principles and rules for the artistic use of directional light, shade, and colour, and includes a chapter on the psychological aspects of colour in lighting. Part IV deals with the practical applications of the principles discussed in previous chapters, in relation to display, studio and stage work, etc.

The author is a Member and Fellow of the Illuminating Engineering Societies of Great Britain and the U.S.A. respectively, and is probably the leading authority on mobile colour lighting.

Design of Concrete Structures. Fifth Edition, 1954. By Leonard Church Urquhart, Charles Edward O'Rourke, and George Winter. 517 pp., 223 illustrations. Publishers: McGraw-Hill Book Company, Inc., 95 Farringdon Street, London, E.C.4. Price: 60/-.

This new, completely revised edition of a well established textbook covers the entire field of reinforced-concrete design. A dual emphasis has been maintained throughout, i.e., the imparting of a basic understanding of the behaviour and performance of reinforced concrete and its design theory, and the development of facility in the practical design of reinforced-concrete structures.

The book has been completely rewritten, and the modifications incorporated reflect the many basic changes in concrete technology and design methods which have taken place since publication of the fourth edition in 1940. While the general method of presentation and arrangement of material has been retained, greater emphasis has been placed on a thorough discussion of basic structural performance, fundamental mechanics, and physical explanation. A new chapter on Modern Development has been added, covering plastic (ultimate) design and pre-stressed concrete.

Selected Papers on Noise and Stochastic Processes. Edited by Nelson Wax. 337 pp., 21 illustrations. Publishers: Dover Publications, Inc., New York 19, N.Y., U.S.A. Price: Paper-bound, $2.00; cloth-bound, $3.95.

In this publication, six basic papers on random processes and their applications to physical problems have been specially selected to meet the needs of physicists, applied mathematicians, and engineers. Together, they serve as a useful reference for two groups of users, i.e., those whose work involves noise characteristics, Brownian movement, and statistical mechanics; and those newcomers to the field who require a useful introduction to advanced noise theory and fluctuation phenomena.

The papers, all unabridged and in English, are by the noted investigators Chandrasekhar, Doob, Kac, Ming, Ornstein, Rice, and Uhlenbeck, and the selections included in the present publication have already become classic. Valuable corrections have been added by the authors.

The titles of the papers are as follows:—*Stochastic Problems in Physics and Astronomy* (Chandrasekhar); *On the Theory of the Brownian Motion* (Uhlenbeck and Ornstein); *On the Theory of the Brownian Motion II* (Ming and Uhlenbeck); *Mathematical Analysis of Random Noise* (Rice); *Random Walk and the Theory of Brownian Motion* (Kac); and *The Brownian Movement and Stochastic Equations* (Doob).

LATEST INDUSTRIAL LITERATURE

1. Transformers for the Electronics Industry. An interesting 6-page brochure describes and illustrates a range of stock-type transformers for use in the electronics industry. This range should fill the need in research and production for a range of high-quality transformers which are suitable for continuous duty at full-load ratings under extremes of climatic conditions. A variety of finishes and styles is available for all ratings, to cover differing requirements of cost and application. The transformers listed are normally available for immediate delivery from stock.

An interesting departure from convention in the rating of H.T. equipment has been made, in that the d.c. output voltage with current, and the d.c. regulation for a given transformer, valve, and condenser combination are listed, thus providing the means of determining the voltage and current accurately at any load over its working range.

2. Steel Guards. A 12-page brochure describes and illustrates a range of fabricated steel guards with many interesting features, including absence of sharp corners and well rounded construction, with a consequent improvement in appearance.

These guards are strong and light, are easily removable, and are virtually unbreakable. Furthermore, cost of painting and fitting times are reduced, and machining is eliminated.

3. Resistance Welders. A 16-page booklet describes and illustrates a range of resistance welders and accessories, with many interesting design features.

One of these machines is a versatile, portable, gun-type spot welder, comprising two separate units, i.e., the arms and the timer, connected by a flexible lead. This machine has unlimited applications for all classes of metal work within its capacity. Welding intensity is in the region of 6000 A, while the pressure at the electrode tips can be varied between 312 and 500 psi, to suit different thicknesses of metal.

Another machine is a new, water-cooled, portable spot welder, intended for the mass production of metal furniture, refrigerators, wire nettings, etc.

4. Electric-Furnace Elements. Details of a range of electric-furnace elements with many outstanding features are contained in a 4-page pamphlet. Each element is a one-piece silicon carbide tube, produced by a completely new method, in which the central hot zone is in the form of a spiral of the requisite length. There are no joints—normally a frequent source of failure.

Hitherto, a major criticism of silicon carbide elements has been their rapid increase in resistance with use. The new elements have a very slow rate of ageing and can thus be operated for comparatively very much longer periods, before replacement becomes necessary. Furthermore, they are entirely suitable for working over a wide range of temperatures, from approximately 1470 to 2870° F.

5. Heat Exchangers. A series of brochures, neatly bound into a loose-leaf cover, to form a catalogue of over 60 pages, describes and illustrates a range of heat exchangers with very high heat-transfer efficiency and permitting extreme flexibility of arrangement.

The sectional type of heat exchanger described is of simple design, consisting of a U-tube shell with a U-tube inner element, finned or plain, as dictated by service requirements. The shell/tube seal is particularly suitable for services involving hazardous fluids. The standard range of sections includes pressure ratings of 600, 900, 1200, and 1800 psi on the shell side; much higher pressures can also be accommodated in the tubes, some of which have been designed for pressures of 10,000 psi. All exchangers are available in a wide range of materials, including stainless steel, cupro-nickel, monel, inconel, etc.

6. Dust Collectors. A high-efficiency dust-collector system, described and illustrated in a 4-page brochure, makes use of the well established multi-cyclone method of dust separation from gases, but incorporates exclusive features, including the introduction of gas through a specially designed slot, special arrangement of the cyclones, and the decantation of large particles into a primary hopper.

Among other advantages of this design are the following:—The coarser and hence more abrasive particles do not enter the cyclones; high recovery efficiencies are achieved with exceptionally low velocities; pressure drop remains constant; there are no guide vanes; each cyclone is accessible for inspection; and maintenance costs are very low.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *NOVEL METHOD OF EXAMINING DUST IN AIR*

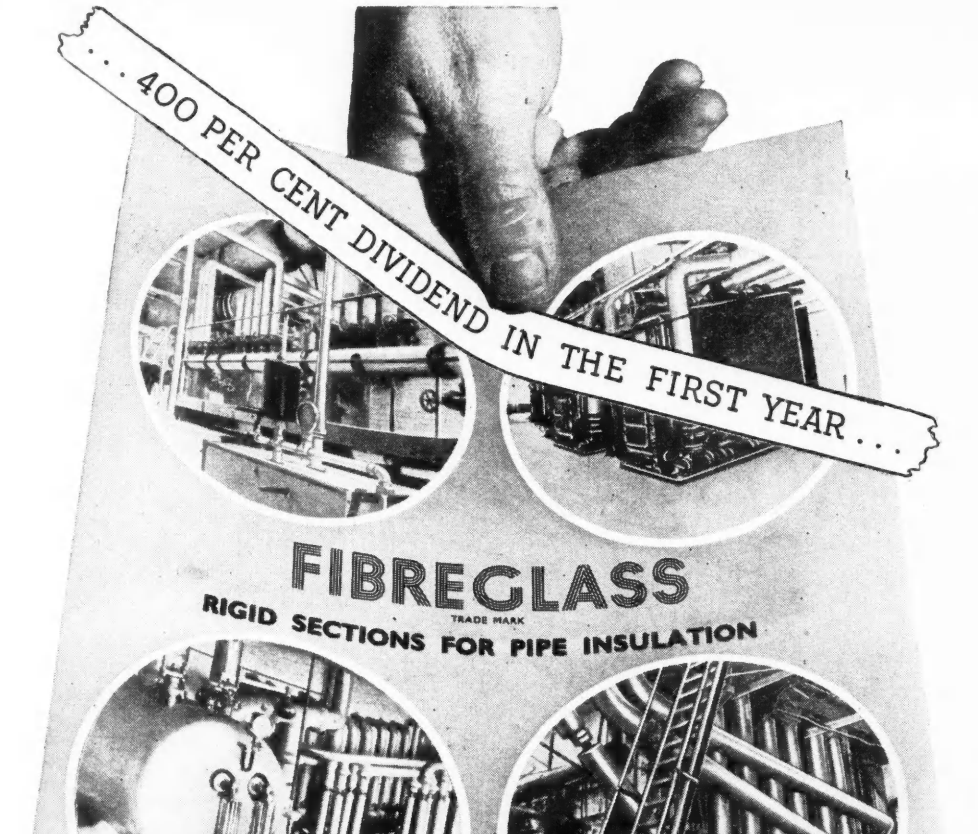
Considering the enormous amount of effluvia from modern industrial plant and other activities causing the generation of dust in large quantities, the availability of reliable instruments for measuring the dust concentration in air is obviously a matter of considerable importance. In fact, in such cases as mining and quarrying operations, the use of such instruments for determining health hazards is indispensable. Several instruments have therefore been developed which, within the range of their applicability, give accurate and consistent results. Particle detectors are available which are designed for the automatic and continuous monitoring of samples of dust-containing gases, but the indication they render is based only on the total concentration of particles present, and does not count the individual particles or discriminate between particles of different size or of different chemical composition. In order to overcome this limitation, an apparatus has been devised in which the particles suspended in the air stream and passed through the device are heated by means of a flame to a temperature at which they become incandescent; the light intensity due to the incandescence of particles is then measured by a photo-sensitive detecting device. Where a count is to be taken only of those particles which have a particular chemical composition, use is made of a light filter which passes only those light flashes which have the spectral characteristic associated with the particular chemical composition, or alternatively, a spectroscope may be used to separate out only the flashes of light having the spectral characteristic in question. Provision can also be made to count only particles above a given minimum size.

● *HIGH-TEMPERATURE CREEP TESTS ON ROTATING DISCS*

In the design of gas turbines and jet engines, the problem of creep deformations and stresses in turbine discs operating at high temperatures over a long period is important. Although many theoretical investigations of rotating discs have been reported in the technical literature, most of these consider elastic deformations and stresses only, or the problem of plastic flow when the disc is brought up to speed; only a very few deal with the theoretical calculation of creep and stress in rotating discs operating for long periods at elevated temperatures. In order to obtain experimental data suitable for verifying theoretical analysis, forged discs of 12% chromium steel were subjected to spin tests at 1000° F for periods up to some 1000 hours. In addition, extended creep tests at 1000° F were carried out on specimens cut out circumferentially from discs, the stresses approximating those of the spin tests. Spin tests were carried out in a high-speed, high-temperature testing machine, in which the disc specimen was mounted on a flexible shaft, with the rotational axis vertical. An investigation of theoretical methods of calculating the creep deformation in such discs showed that the methods based on the Mises criterion gave creep deformations which were too low, compared with the values found by test, i.e., the computed values were not on the safe side for design. It is stated that considerably better agreement between test and theoretical results is obtained, if theoretical treatment is based on the maximum-shear theory. One possible reason for the better agreement obtained by using the maximum-shear theory is that the latter attaches greater importance to the effects of tangential stress acting in the direction of tangential specimens used for evaluating creep strength.

● *NEW GLASS-FIBRE PRODUCT*

Successful efforts are being made to develop a new structural material of glass fibre for various applications. The results obtained so far are reported to indicate that the new material will be suitable for higher temperature applications than is possible with present-day glass-fibre products. Furthermore, the new material is claimed to possess higher mechanical strength, a more favourable strength weight ratio, and a very high resistance to the usual corrosion agents. Another favourable point cited is that the raw materials used in the manufacture of the new product are readily available. Under the development programme now under way, new methods of bonding glass fibre have been devised and these will produce laminates and tubular products of superior strength. Instead of the conventional method of bonding glass fibre with resins and organic materials, the new methods combine metals and inorganic substances or combinations or both. Glass-fibre filaments are formed in the usual way by the use of appropriate refractory furnaces and bushings. As the filaments emerge from the furnace at high speed, they are



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individually coated with metallic and other inorganic substances. Metal coatings, such as iron, nickel, molybdenum, aluminium, zinc, lead, tin, and copper, have been applied. The coated fibres are then bonded and compacted to form tubular products and laminates in a subsequent stage of the process, which involves the application of suitable conditions of heat and pressure, with or without the use of the more common flux materials. When they are commercially available, it is expected that the new materials will find important industrial applications, such as in the form of tubing for the oil and chemical industries.

● *ELIMINATION OF EDGE CRACKING IN ROLLED STRIP*

It has been discovered that cracking along the edges of steel strip during rolling, causing considerable wastage of steel and lower output, may be largely prevented by making the edges of the strip square and as smooth as possible. Edge cracking is caused by tensile stresses which develop along the edges of the strip as it passes through the rolls. Tensile stresses are less severe when the sheet edges are square than when they are convex or concave in cross-section, as is often the case as a result of previous rolling. The effect of grinding the edges is said to be striking. With a 1·3% carbon steel, which is normally difficult to roll, tests have shown that, when the edges are rounded, as they are in practice, cracking starts as soon as the strip is reduced beyond 12%. When the edges of similar strip are first ground or milled square, a reduction of more than 60% can be made without cracking. Shearing is not effective, as this leaves the edge cold-worked and may even cause incipient cracking. A simple device has been developed and patented for grinding the edges square, thus reducing the severity of the tensile stresses and edge cracking. In this process, the strip is ground by cup-type grinding wheels held under pressure against the edges as the strip passes between pairs of rolls. With difficult alloy steels and in narrow strip of gauges below 0·02 in., it is considered to be far more economical to grind the edges square during the rolling process than to shear off 15% or more of the strip afterwards, because the edges have cracked.

● *STRESS REMOVAL BY ELECTROLYTIC TREATMENT*

A recent patent describes a process in which the pressing of stainless steel parts is facilitated. It is well known that, when pressing a part of such a material, stresses can be set up in the surface and can result in fractures or cracks whenever the part is subjected to a further pressing operation. These stresses can, of course, be minimised or eliminated altogether by heat treating the material between pressings, but the inventor suggests that a better method consists in removing a thin surface layer of metal between pressing operations. In the method proposed, the metal part, after the first pressing, which tends to set up stresses in the surface, is subjected to an electrolytic treatment. In this treatment the work is made the anode, so that the electric current removes a small depth of material. If the piece requires more than two pressings, electrolytic treatment is carried out between subsequent pressings. The depth of material to be removed by the electrolytic treatment is stated to be preferably within the range of 0·005 to 0·00025 in., but a greater depth could of course be removed if it is considered desirable. An interesting application of the process is in the manufacture of jet-engine flame tubes, which are made from a high-percentage chrome-nickel alloy. These tubes are pierced with a large number of holes and in some cases pressing is subsequently carried out adjacent to or around each hole. It is claimed that, by subjecting the tube to electrolytic treatment after forming of the holes, no cracks will occur when the tube is subjected to the final pressing, as the tendency to crack formation will at least be considerably reduced.

● *PRODUCING SILICON CARBIDE SURFACES ON GRAPHITE*

A novel process has been perfected and should go a long way in solving the problem of manufacturing high heat- and wear-resisting jet nozzles for rockets and similar parts where long service life is not required. The underlying principle of the new process is the conversion of the surface of a graphite body into silicon carbide. This is effected by exposing the surface to silica vapour. Considering the case of a nozzle of venturi shape, the machining of such a nozzle by means of conventional edge tools of appropriate shape is first carried out. The nozzle is then placed on a grating of graphite bar above a graphite crucible containing silica sand and the whole assembly is enclosed in an outer graphite crucible. A chimney is provided to vent the outer crucible. A pyrometer tube is also inserted, in order to be able to measure the process temperature. Heating of the crucible and its contents is accomplished by induction heating. For this purpose a water-cooled copper coil is placed around the outer crucible and energised by a medium-frequency alternator. As soon as the silica sand has reached a temperature of 1700° C it begins to melt, and when the inner crucible has reached 2240° C, the molten silica boils. The silica vapours sweep the surface of the graphite nozzle contained in the crucible and react on the graphite to form silicon carbide. Considering that, because of its high resistance to chemical corrosion, graphite is now finding extensive application in heat exchangers, there would appear to be a good promise of increasing the wear resistance and oxidation resistance of the heat-exchanger surfaces by the new process.

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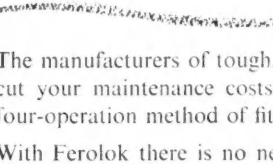

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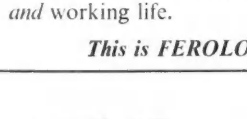
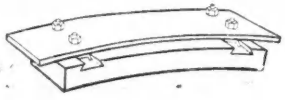


FEROLOK bolts hold the "keepers" securely in the grooves and the dovetail action keeps the lining securely fastened to the band.



When the bolts are loosened, it simply slides into position (as shown). The nuts are then tightened and the job is done.

To reline:—Slacken off the bolts. Slide off old lining. Slide on new lining. Retighten bolts.

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● *INFLUENCE OF PRECOMBUSTION UPON ENGINE KNOCK*

A new technique has been devised which makes it possible to study the knock effect of precombustion reaction products in terms of conventional knock-test units and to establish relationships between fuel reactivity and knock. The equipment used for this purpose consists of a pair of variable compression-ratio, valve-in-head, single-cylinder engines. The fuel-air charge is inducted through a standard carburetter and intake manifold by the first, or motored, engine. In this engine, which is driven by an electric motor, the charge is compressed but not fired ; the charge is then expanded and exhausted into a manifold leading to the intake port of the second, or fired, engine. The motored engine is driven by a variable-speed motor, while the fired engine is coupled with a constant-speed synchronous motor. The air supplied to the first engine is kept at constant humidity and supplied at an intake temperature of 150° F. The connecting manifold walls are heated externally, in order to maintain the same temperature at the intake of the second engine. The knocking tendency of the charge leaving the motored engine is measured in the fired engine in terms of that compression ratio which results in audible-trace knock. For each fuel to be tested, the motored engine is operated at a compression ratio of about 5:1 and the knocking tendency of the exit gases is measured in the fired engine. As the compression ratio of the motored engine is increased, a point is reached for most fuels at which the anti-knock value of the charge from the motored engine is decreased. Knock determinations are made at further small increases in compression ratio until the charge self-ignites in the motored engine.

● *AUTOMATIC PLOTTING OF ELECTRIC FIELD LINES*

Inherent disadvantages of the electrolytic method of determining electric field patterns are that its accuracy is impaired by polarisation effects and surface tension. Within recent years attempts have therefore been made to obtain field plots by other means, such as the use of a resistive network or the employment of uniformly resistive paper. All these methods involve either the determination of the potential prevailing at fixed points, as in the resistive network, and subsequent interpolation to determine specific field lines, or manual searching for specific field points and the subsequent manual plotting of the lines connecting these points. A considerable improvement on these methods has been achieved by the development of an automatic field plotter which is capable of producing continuous field lines without manual searching or plotting and of drawing these lines directly on the plot of the electrodes. The new method is based upon the combination of the resistive-paper technique with the use of an X-Y recorder. The electrodes, the field distribution between which is to be investigated, are painted with silver paint upon the resistive paper and are then polarised by means of a d.c. battery. The field set up in the resistive paper is then investigated by means of the pick-up probe of an X-Y recorder, which senses the voltage locally prevailing. To obtain an equipotential field line, the arm on which the pick-up probe travels is caused to move at a right angle to the direction in which the voltage is applied across the paper. For a given potentiometer setting, the probe will then trace a single equipotential line. By changing the potentiometer setting and moving the probe backwards and forwards across the paper, a complete series of equipotential lines can then be obtained. Obviously, a paper with uniform resistive properties is necessary, and it should be possible to sense the local voltage prevailing with light contact pressure by means of a lightweight probe.

● *PRODUCTION OF CONTAINERS BY IMPACT EXTRUSION*

Impact extrusion has become an important manufacturing technique in the production of aluminium and zinc containers for such purposes as, for instance, capacitor casings. So far, it has not been possible in practice to manufacture by impact extrusion thin-walled containers which are divided into two or more compartments by thin walls extending in the direction of extrusion. According to a new, patented manufacturing technique, the problem is solved by reinforcing certain portions of the container walls and providing a stripping-off device which engages the reinforced wall portions. In the manufacture of capacitors by established methods of impact extrusion, it is common practice to shape the mould or die in such a form that, during manufacture of the capacitor casing, the latter is left in the die when the ram is withdrawn. This is achieved by producing at the bottom of the casing an edge which engages with a part of the die. However, this method requires a split die, in order to permit removal of the casing after extrusion. Besides increasing the cost of the die, this method also requires the bottom of the casing to be made comparatively thick, so that an edge can be formed. This requirement is eliminated by the new method, in which the casing is withdrawn from the die together with the ram after it has been moulded. Removal of the casing from the ram is then effected by the stripping-off device. Since considerable friction must be overcome in order to strip the part off the ram, reinforced casing walls are provided upon which the stripping-off device can act. Obviously, this improvement in impact-extrusion technique can be applied to many products, and shows how apparently insuperable manufacturing difficulties can sometimes be overcome very simply.

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● *PRODUCTION OF POROUS SINTERED METAL PARTS*

A new method of producing porous sintered metal parts of good dimensional accuracy and density has been developed. In this method, a preformed plastic mass containing metal particles and a heat-fugitive binder is heated to sintering temperature, so that the binder is volatilised and the metal particles are sintered together. The new method recognises that care must be taken to control the amount of shrinkage which naturally occurs between the time that the binder-containing plastic mass is introduced into the sintering furnace and the time of removal of the finally sintered part from the furnace. This shrinkage is caused by the drawing together of the powdered metal particles as the plastic binding material is being removed. According to the claims of the inventors of the process, the shrinkage during volatilisation of the binder can be controlled to within very close limits if a non-oxidising protective gas stream is passed over the parts during heating in such a way that the vaporised matter resulting from the decomposition of the binder is removed at a controlled rate. Close control of the rate of removal of the binder is necessary, because rapid removal would leave the particles of powdered metal with relatively little surface contact and large void areas. There are several methods in which the rate of volatilisation can be controlled. First among these is the control of the rate of heating of the preformed mass until sintering temperature is reached. Another method consists of controlling the rate at which the gas used to carry off the volatilised binder is introduced. Finally, the process may be controlled by the composition of the binder material. The latter is usually a thermally depolymerisable polyolefin, such as, for instance, polybutene, polystyrene, or polyethylene.

● *BLENDING AND MIXING OF FUEL OIL*

An ultrasonic method, combined with electronic gear, has been developed for controlling the blending of fuel oil for marine use. It is claimed that the new method is proving superior to conventional mixing procedures because it ensures the accurate blending of light and heavy fuel oil to conform to varying burner characteristics in different ships. With this new technique the viscosity of the fuel oil is measured by an ultrasonic viscometric device. A probe attached to the instrument is inserted into the line carrying the final blend. The amount of energy absorbed by the fluid from the probe as it oscillates at high frequency indicates its viscosity. Since viscosity varies with temperature change, a compensating unit is incorporated to adjust the measurement to varying temperatures. As viscosity varies, the ensuing reaction of the probe is passed on to an electronic control unit which automatically controls the flow of light fuel oil to the mixture by opening or closing the supply valve, so that the viscosity of the mixture is maintained at the specified value. It is claimed that the new system will not only assure more accurate blending of fuel oil, but that it is also expected to result in substantial savings by conserving the amount of light fuel oil used, the latter being considerably more expensive than the heavy oil. In the conventional method, the blending procedure is worked out in advance by mathematical calculations, but this does not take into account any variables which might affect the measurements. In contrast, the new method appears to eliminate variables adversely affecting accuracy, such as errors in the pumps and meters feeding the oil into the tanks, or possible stratification in the tanks.

● *SURFACE FINISH OF IRON CASTINGS*

A recent report gives valuable information on the factors which influence the surface roughness of iron castings. This roughness is known to be due to penetration of the porous mould by molten metal. The depth to which the sand is penetrated is determined by metal pressure, surface tension, and contact angle, and also by the size of the pores between the sand grains. If the difference between the metal pressure and the surface tension forces is sufficiently great, all sand hotter than the solidification temperature of the metal may be penetrated. Penetration is opposed by the surface tension of the liquid metal to an extent governed by the contact angle, provided the angle is between 90 and 180 deg.; smaller angles allow the surface tension to draw metal into the sand, even in the absence of metal pressure. Experiments were made using different types of silica sands and natural sands, the silica sands being bonded with bentonite. No general relationship applicable to all sands could be found between ramming of the sand or the moisture content of the sand, and surface finish. However, for many of the natural sands tested, increased ramming improved the finish; lightly rammed specimens, made in materials of high clay and water content, yielded the roughest castings, independent of grain size distribution. It may be that the clay envelope round the larger grains collects the finer grains and increases the average effective grain size, yielding rough castings. The effects of additions of pitch and coal dust to the sand were also studied, and it was found that the improvement in finish was most marked in the case of silica sand.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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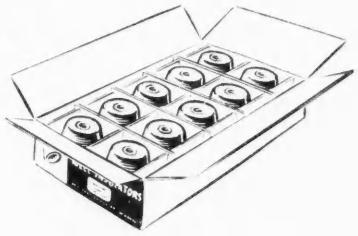

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